

CHINESE INK-AND-BRUSH PAINTING WITH FILM LIGHTING
AESTHETICS IN 3D COMPUTER GRAPHICS

A Thesis

by

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ABSTRACT

This thesis explores the topic of recreating Chinese ink-and-brush painting in 3D computer graphics and introducing film lighting aesthetics into the result. The method is primarily based on non-photorealistic shader development and digital compositing. The goal of this research is to study how to bring the visual aesthetics of Chinese ink-and-brush painting into 3D computer graphics as well as explore the artistic possibility of using film lighting principles in Chinese painting for visual story telling by using 3D computer graphics.

In this research, we use the Jiangnan water country paintings by renowned contemporary Chinese artist Yang Ming-Yi as our primary visual reference. An analysis of the paintings is performed to study the visual characteristics of Yang's paintings. These include how the artist expresses shading, forms, shadow, reflection and compositing principles, which will be used as the guidelines for recreating the painting in computer graphics. 3D meshes are used to represent the subjects in the painting like houses, boats and water. Then procedural non-photorealistic shaders are developed and applied on 3D meshes to give the models an ink-look. Additionally, different types of 3D data are organized and rendered into different layers, which include shading, depth, and geometric information. Those layers are then composed together by using 2D image processing algorithms with custom artistic controls to achieve a more natural-looking ink-painting result.

As a result, a short animation of Chinese ink-and-brush painting in 3D computer graphics will be created in which the same environment is rendered with different lighting designs to demonstrate the artistic intention.

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NOMENCLATURE

2D	Two-dimensional
3D	Three-dimensional
CG	Computer Graphics
NPR	Non-Photorealistic Render
DP	Director of Photography

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1. INTRODUCTION

1.1 Motivation and Inspiration

By using the ink-and-brush medium, Chinese painters have been creating paintings on paper or silk scrolls for thousands of years. Chinese ink-and-brush painting has its unique visual characteristics in many ways. It does not emphasize one-point perspective nor does it aim to express the shades of color of a subject in relation to a fixed source of light as traditional western painting does. Therefore, it usually does not have any physically accurate lighting, shading and shadow (see Figure 1.1).

It would be interesting to explore how traditional Chinese ink-and-brush painting would look with the changes in lighting, and how it would appear in digital media such as 3D computer graphics. The inspiration behind this idea also comes from the application of film lighting aesthetics in 3D computer graphics. In the world of filmmaking and photography, cinematographers and lighting artists use light as a powerful tool for conveying mood and visual story telling (see Figure 1.2). This is achieved by adjusting different aspects of lights such as quality, direction and color. Although they are very different considering the methods, tools and medium being used, traditional Chinese ink-and-brush painting essence and film lighting aesthetics share an important similarity - they both emphasize expressing the characteristics of the subject and the vision and emotion of the artist rather than just depicting a scene in a physically accurate way. This makes us interested in attempting to merge these two types of art together by introducing film lighting aesthetics into Chinese ink-brush painting.

Instead of working with traditional media, ink, brush and paper, our research uses tools and methods in 3D computer graphics. In recent years, many works have



(a) A Chinese ink-and-brush landscape painting by ZhuDa (1626–1705)



(b) A Chinese ink-and-brush landscape painting by Shitao (1642–1707)

Figure 1.1: Two examples of Chinese ink-and-brush landscape painting [29].



(a) A still image from film “Blade Runner” [7].



(b) A still image from film “House of Flying Daggers” [26].

Figure 1.2: Examples of film lighting principles applied in movies for enhancing visual story telling: (a) A still image from film “Blade Runner” (1982), in which the director of photography (DP) uses strong rim light and an extreme high lighting ratio to enhance mood. (b) A still image from the film “House of Flying Daggers” (2004), where the DP used atmosphere effect to create drama.



(a) A still image from short-film “Paperman” [14].



(b) A still image from video “Twinnings Sea” [20].

Figure 1.3: Examples of 3D animation with painterly rendering style. (a) A screenshot from short film Paperman(2012), in which NPR technique was developed to create a traditional 2D hand-drawn rendering style, while lighting and shading qualities of 3D animation are still maintained. (b) A screenshot from the commercial Twinnings Sea (2011), where special shading and compositing workflow were used to create the oil painting look.

been done in computer graphics to recreate painterly rendering styles (including traditional Chinese ink-and-brush painting). Non-Photorealistic Rendering (NPR) workflows have been applied in 3D computer graphics animation productions to create NPR works like short-films “Paperman” (2012) and “Twinnings Sea” (2011). Both works have a graphic quality of 2D hand-painting style and changes of light and shadow for enhancing visual story telling (see Figure 1.3). These works also motivate us to try bringing the Chinese ink-and-brush painting style into the 3D computer graphics and utilizing the techniques in computer graphics to apply film lighting aesthetics in Chinese ink-and-brush painting.

1.2 Introduction

The goal of this research is to explore the artistic possibility of bringing Chinese ink-and-brush painting into 3D computer graphics and applying film lighting aesthetics in it by using CG as the medium. We chose the Jiangnan water country paintings from Yang Ming-Yi as our primary visual reference. It should be noted that

this research is not intended to copy specific painting, nor create physically accurate result to simulate Chinese ink-and-brush painting in 3D Computer Graphics.

This research will focus on (1) How to represent tone and value in computer graphics in a way similar to Chinese ink-and-brush painting. (2) How to bring in and handle the changes of lights and different rendering effects in Chinese ink-and-brush painting, which are commonly seen and come free in physical lighting. These include: shadow, atmosphere effects, reflection, etc. (3) How to capture the irregularity in shapes and forms in computer graphics, which is commonly seen in Chinese ink-and-brush painting. (4) How to create depth and arrange composition in CG to match the aesthetics of Chinese ink-and-brush, which does not emphasis one-point perspective. (5) How to implement film lighting aesthetics in 3D Chinese painting to enhance mood and story-telling. The research will be focusing on the rendering aspect of 3D animation. Such aspects as animation will not be explored in this project as they exceed the scope of the study. Also, This research will be recreating Chinese ink-and-brush painting through 3D computer graphics, so the tools and workflow developed in this research do not intend to be applied to any physical painting process.

The process begins with a visual analysis of landscape paintings from Yang Ming-Yi. The analyzing process will be primarily based on four aspects: (1) value and tone, (2) shape and form, (3) water reflection, (4) layout and composition. Then several non-photorealistic shading methods are presented to match the visual characteristics from the analysis in computer graphics. The methods developed here are intended to give the user enough artistic controls on the final image by placing virtual lights in 3D scene, adjusting NPR shader and compositing parameters. To implement the methods, we design and model a virtual 3D scene to represent the landscape painting. Then the methods are applied into a 3D rendering and 2D digital compositing work-

flow, which is used to render the 3D scene with the Chinese ink-and-brush painting styles. Finally, a landscape animation of 3D Chinese painting is created, in which different lighting designs are used in the same environment based on film lighting aesthetics. This research uses existing computer graphics softwares as development tools. 3D modeling is done with Autodesk Maya. NPR shader development and rendering process happens in Pixar’s Renderman. And the digital compositing is executed in Nuke, a node based digital compositing software produced and distribute by The Foundry.

The rest of the thesis is organized as follows. Section 2 details background information on the history and theories of Chinese ink-and-brush paintings, film lighting concepts and aesthetics. And then it summarizes previous researches related with non-photorealistic rendering. Section 3 presents an artistic analysis of the visual references, and then discusses the NPR shading methods to match the visual characteristics in computer graphics. Section 4 describes the process of designing and building the 3D scene, as well as the implementation of NPR shading methods in Section 3. Section 5 presents conclusion and discusses the future works.

2. BACKGROUND AND LITERATURE REVIEW

In this chapter, we will talk about the background information for our research. First, we will provide a brief discussion regarding the history, theories and techniques of Chinese ink-and-brush painting. Then, we will take a look at the theories and principles for good film lighting design. At last, we will review some of the previous works in non-photorealistic rendering related with rendering Chinese ink-and-brush painting in computer graphics.

2.1 History, Theories and Techniques of Chinese Ink-and-Brush Painting

Chinese traditional painting is highly regarded throughout the world for its theory, expression, and techniques. In the history of Chinese paintings, figure painting was the first genre to appear and the earliest painting was found on silk during Warring States period. Mountains, rivers, flowers and birds first served only as the background elements in figure painting but then gradually developed into independent genres. Chinese landscape painting, however, flowered during the Song dynasty (AD 960-1279) and became the most important genre [29].

Chinese painter utilizes the forms he finds in nature, such as ovals, circles, and geometric lines, which are also found in Chinese calligraphy. Utilizing the same tools (brushes and ink), all Chinese paintings ranging from landscapes to human figures share the same movement, rhythm, and harmony in calligraphy [25] (see Figure 2.1).

Different from western painting, Chinese painting is not restricted by the focal point in its perspective and a fixed source of light. It is free in describing the objects, and places more emphasis on the painter's sentiment and the overall arrangement of the picture to carry philosophical ideas about the universe and humanity[11]. The most important factors for Chinese painting are the special pedagogy, the close re-

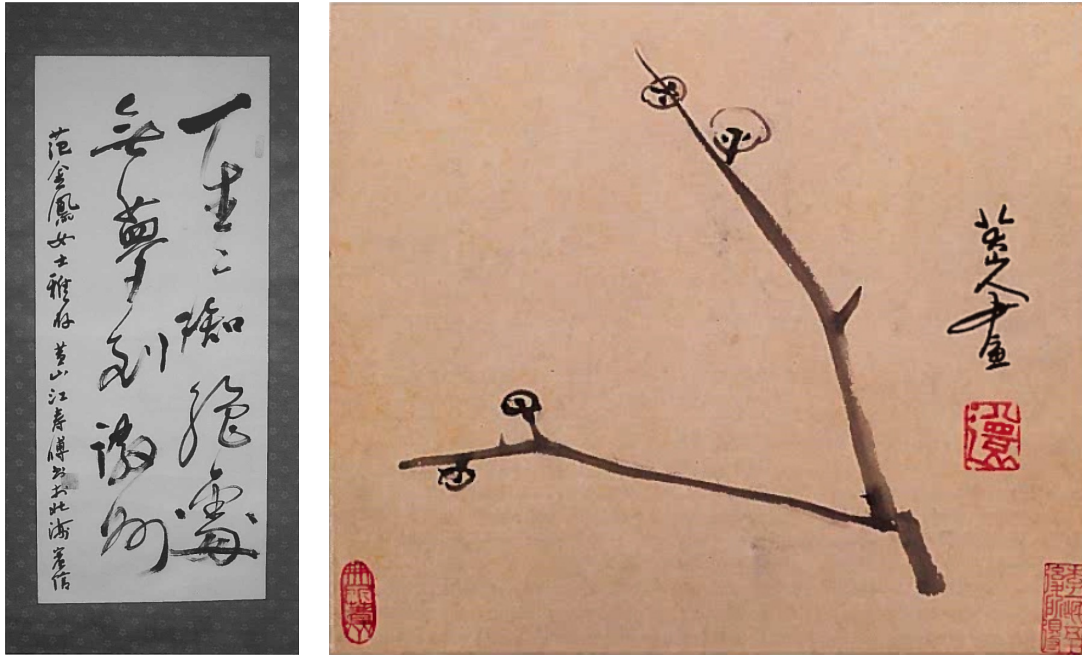


Figure 2.1: Comparison of tradition Chinese painting and Chinese calligraphy[8].

relationship with the painter's personality and the unique Chinese philosophy. With the belief that painting should be an expression of the painter's knowledge and temperament, traditional Chinese ink-and-brush painters are trained not to focus on depicting the object's physical shape accurately, but to express the mood and the spirit of the subject. Among the "Six principles of Chinese Painting" established by Xie He, a writer, art historian and critic in 5th century China, the first and most important principle is 'Spirit Resonance'. This refers to the flow of the energy and vitality that encompasses the theme, work and the artist. Without such spiritual connection between artist and subject, the paint loses its essence.

Chinese painting and its theory have roots within China's major philosophies significantly including Confucianism and Buddhism. Under such philosophical ideas, the way Chinese people view the universe and human beings have evolved into a unique system, which promotes a humanistic spirit greatly different from the West.

In Chinese painting, the empty and solid parts of the image are usually related to the concept of emptiness and nothingness in the Confucian theory. “Confucius regards emptiness as the fullest and nothingness the greatest [4].” Such theory has governed art production in China through many generations [11]. Also, the spreading of Buddhism throughout China along the silk road brought great demand for copying Buddhist text and art. Many paintings were created related to Buddhist figures, subjects and stories. This greatly broadened the range of subjects in Chinese painting and also established the deep connection between Buddhist concepts and Chinese painting theory - to reveal the inner harmony of man and nature. Another way of thinking unique to the Chinese painting is that of personifying scenes or subjects such as mountains, rivers, animals and plants in paintings so as to identify with the ethics and humanistic spirit revealed in the Confucian and Buddhist theory.

2.2 Film Lighting Principles and Aesthetics

In the world of film-making, cinematographers and lighting designers use lighting as a powerful storytelling tool. The primary purpose of film lighting is to support the story by contributing to the overall visual structure of the film. In any case, there is more to film lighting than simply making the scene visible and photographing them. The mood of the film must be carefully crafted with lighting.

In film production, each film has a director of photography (DP), whose job is to work with the director to develop a look for the lighting in a film. In other words, DP plays an essential role in directing lighting for every shot in order to create right mood and emphasize story point. In her chapter “Storytelling through Lighting: a Computer Graphics Perspective, in the book *Advanced Renderman*, Sharon Calahan, a DP from Pixar Animation Studio, discusses five important fundamentals of good lighting design. They are [1]:



Figure 2.2: A still image from the film “Oliver Twist” demonstrating how lighting is used to direct the viewers’ eye. In this shot, the DP intentionally placed the main character (1st left) closer to a soft diffuse light source from a window. As a result, the main character receives more illumination, which creates a value contrast with the other two background characters on the right. This directs the viewers’ eye to the main subject in this shot [9].

- Directing the viewers’ eye
- Creating depth
- Conveying time of day and season
- Enhancing mood, atmosphere and drama
- Revealing characters’ personalities and situations

To achieve these goals, lighting artists usually need to adjust different aspects of lights. They include: quality (hard or soft), direction, altitude, color, intensity, texture. Figure 2.2 to Figure 2.6 shows several examples of good lighting design based on each of the five fundamentals discussed above.



Figure 2.3: A still image from the animation film “KungFu Panda” demonstrating how lighting is used to create depth. In this shot, the lighting artist uses an exaggerated lighting fall-off from foreground to background to create a sense of depth in the prison space. This creates an impression that the story happens in a very large space [13].



Figure 2.4: A still image from animation film “Ratatouille” demonstrating how lighting is used to convey time of the day. In this shot, a warm sun beam is shining through the window from a very low angle. The color and direction of the light successfully mimic the lighting condition of a sunny afternoon, and help to enhance the warm feeling of this shot [2].



Figure 2.5: A still image from the film “Blade Runner” demonstrating how lighting is used to enhance mood, atmosphere and drama. In this shot, DP uses a very hard key light to create sharp shadows on the character with a high lighting ratio. This gives the shot a mysterious and dramatic mood [7].



Figure 2.6: A still image from the animation film “Ratatouille” demonstrating how lighting is used to reveal characters’ personalities and situations. In this dialog scene, Anton Ego (the character on the right) was illuminated by a cool-color light from below, which reinforces his creepy personality and dominant role in this conversation [2].

2.3 Previous Works in Non-Photorealistic Rendering

In computer graphics, Non-photorealistic Rendering (NPR) refers to the area which focuses on enabling a wide variety of expressive styles for digital art. Traditional computer graphics focus on photorealism. By contrast, NPR is inspired by artistic techniques and styles like painting, drawing, technical illustration, and animated cartoons.

A number of studies have been done in NPR related with Chinese Ink-and-Brush painting. Some of them focus on converting an existing image into the style of Chinese painting [5, 22, 30, 18, 28]. For instance, Cheok, Lim and Tan propose an image processing system that can transform a landscape photographs and make it look like a Chinese ink-and-brush painting [5]. By using a mathematical model to physically simulate the diffusion between ink and absorbent paper, Wang presents a painterly rendering algorithm which can convert a digital image into a color ink painting [22]. In 2011, Ning, Laga, Saito and Nakajima propose a sketch-based interactive NPR system which allows users to define the contours of any complex shape in an image and then render the shape with ink brush strokes based on the user input and color information in the image. In this way, the subject in the image will be rendered as if it is painted with traditional oriental brush strokes [18]. Yang, Yu and Lee also present an algorithm based on mean curvature flow to render a Chinese Ink-and-Brush painting from an image of pine trees [28].

Apart from using image processing algorithms to manipulate digital images, some research focuses on developing digital painting models and systems which can simulate the tools and processes of Chinese ink-and-brush painting [31, 27, 6, 24, 12]. Yu, Lee, Cho and Lee present a digital drawing system for creating oriental paintings in computer graphics, in which they propose and implement a local equilibrium model

which calculates how water and ink moves [31]. Xu, Tang, Lau and Pan propose a method to create models representing the hairy brush, paper and ink used in Chinese calligraphy [27]. By using this method, the user can create highly realistic looking calligraphy and the final system of their research provides a user-friendly interface, which allows user to control the result artistically. Additionally, by combining physical simulation with implicit model and image-based methods, Chu and Tai present a way to simulate how ink disperses on an absorbent paper and implement the method into a digital painting system able to create a realistic looking ink dispersion effect [6]. Way and Shih also propose a way of synthesizing rock texture in Chinese landscape painting, which allows users to paint interactively [24].

In addition to the works mentioned above, which primarily deal with NPR methods on 2D areas for creating Chinese ink-and-brush painting, a number of studies also focus on rendering Chinese painting in computer graphics from 3D models [32, 21, 23, 3, 15]. For instance, Zhang, Sato, Takahashi, Muraoka and Chiba present a rendering method for creating Chinese painting style tree trunks and branches from a 3D skeleton model [32]. Sato, Fujimoto, Muraoka and Chiba propose a way to render trees in Chinese paintings from polygon models by realizing Kuo, Ten and Shun brush stroke techniques on the 3D surface [21]. And in 2002, Way, Lin and Shih present a method to draw trees in Chinese painting style from 3D polygon model by generating the outline and texture based on the shade and orientation information of the model [23].

Apart from developing its own system for the research, some of the studies also use existing 3D software packages to create Chinese paintings from 3D models [3, 15]. For instance, Chan, Akleman and Chen present a method for creating 3D Chinese paintings in CG by modeling the brush strokes and developing procedural shaders to make each 3D model looks like a brush stroke in Chinese ink-and-brush painting

[3]. In 2006, by using existing commercial 3D software packages, Li also explores the possibilities of using 3D computer graphics to create 3D living Chinese landscape paintings by introducing dynamic animation effects in a number of elements like cloud, fog, water and trees [15].

Compared with the NPR methods for rendering Chinese painting in 2D areas, having actually 3D polygon models make it possible to introduce more dynamic effects into the result by using camera movement and lighting. Since one important goal of our research is to explore the artistic possibility of merging traditional Chinese painting with film lighting aesthetics, we will undertake the approach of using existing 3D software packages in creating the final result.

3. VISUAL ANALYSIS AND METHODOLOGY

In this chapter, we propose the NPR shading approach used for creating our final animation. First, we present a visual analysis on the visual references to abstract the essential characteristics in Chinese ink-and-brush for us to match in the digital work. And then, based on the result of our analysis, we will discuss the detailed NPR shading approach to match each of the characteristics.

3.1 Visual Analysis

In this research, we use Yang Ming-Yi’s landscape painting as the primary visual reference. Among contemporary Chinese painters, Yang Ming-Yi retains a distinct identity as a “Chinese” painter in his paintings while also incorporates many qualities that are commonly seen in western paintings. For example, he retains the familiar materials of brush, ink and paper and uses traditional painting techniques in Chinese painting such as ink wash, wet brush and dark outline techniques. Meanwhile, Yang’s paintings also imply having a common vanishing point as seen in western painting, by using the three-quarter view for the objects. Further, his landscapes paintings always obtain different elements from foreground, midground to background that are unified by a continuous spatial field. The integration of these elements in his paintings, that is, eastern and western, gives a certain realism, which can be a useful guideline for creating Chinese paintings in 3D computer graphics. It should be noted that the goal for this research is neither to copy the visual references into 3D computer graphics, nor to simulate the ink behaviors and achieve the visual accuracy of how ink-and-brush paintings look, but to use his paintings as primary visual reference for studying and resembling the style and aesthetics of Chinese ink-and-brush painting.

Here we choose some of the Jiangnan water country landscape paintings from

Yang Ming-Yi for visual analysis. The purpose of the analysis is to provide guidelines for creating digital work in CG that matches and captures the visual characteristics and aesthetics of Chinese ink-and-brush painting. The results of this analysis yield a list of essential characteristics and artistic aspects derived from Chinese painting, which can be categorized as follows:

- Value and Tone
- Shape and Form
- Water Reflection
- Layout and Composition

Based on the analysis, specific solutions will be presented, which are suited to recreate these visual characteristics in computer graphics.

And for each aspect, we choose different paintings for analysis. The goal is to try to find out the universal visual aesthetics shared by the art works. And it should be noted that the visual characteristics from each analysis is not just specific for a particular painting.

3.1.1 Value and Tone

In this section, the analysis is based on value and tone. It refers to how the artist uses different shades of black to convey lighting, forms and textures. This also includes the use of different levels in black to give depth and atmospheric information.

In Chinese paintings, the painters mainly use black ink. To create different values and tones, they use the brush to load ink and water with different ratio to achieve different shades of ink [8]. Figure 3.1 shows two of Yang Ming-Yi's landscape paintings. In the left one, the use of different shades of ink to render light and shadow can



Figure 3.1: (a) An example of Jiangnan water country landscape painting by Yang Ming-Yi, which demonstrates how the painter use different shades of ink to render light and shadow [17]. (b) Another example from Yang's landscape painting, in which he uses different levels of blackness to create details in texture on buildings' surfaces caused by weathering effect [17].

be clearly observed on the left side of the image, where the painter utilizes different levels of blackness in ink to paint the shadow and light area of the stone ground. The transition between different shades of ink can be seen because of the ink diffusion activities on the paper.

Apart from this, the painter also uses different levels of blackness to convey details in texture on the buildings caused by weathering and natural effects. In Figure 3.1 (b), the weathering effects created by rain running down the buildings' surface is painted by adding different level of blackness with brush strokes in vertical direction. This adds detailed textures onto the subjects.

In our visual references, the changes of value and tone, created by using different shades of ink, are also used to create atmospheric effects and indicate depth. Figure 3.2 shows two paintings, in which Yang Ming-Yi uses a lighter tone of ink to render the buildings as they become further away.



Figure 3.2: Two examples of Jiangnan water country landscape paintings by Yang Ming-Yi, in which different shades of ink are used convey depth and atmospheric effects [16].

3.1.2 Shape and Form

Visual analysis in this subsection is based on the artistic aspect of shape and form. This includes how the brush is used to create irregularities in the shape and form of different subjects such as boats, buildings and bridges.

In Chinese ink-and-brush paintings, a great amount of irregularities created by brushworks and ink diffusion effects on the absorbent paper can be observed in the outlines and edges of the subjects. Figure 3.3 shows a close-up image of the buildings and bridges in one of Yang Ming-Yi's paintings, in which we can see the details of small noise patterns and imperfections around the edge region of the walls, bricks and roofs. Also, it is worth to mention that the irregular patterns sometimes are carefully controlled by the artist and painted differently for the foreground and background elements. For instance in Figure 3.3, the buildings and mountains in the background are painted with a higher level of irregularities on edges than the elements closer to the viewer. And to finalize the shape and form of the objects, the artist adds a dark outline on the edges by using dark ink to draw thin brush lines.



Figure 3.3: A close-up image of Yang Ming-Yi's painting showing the regularities in edges and boundaries create by brushworks and ink diffusion effects [17].

3.1.3 Water Reflection

Since water surface is a really common subject in our visual references and has some unique visual characteristics. In this section, we take a closer look at how Yang Ming-Yi renders the water reflection in his paintings. This refers to how he expresses different values and tones, as well as the shape languages in the reflection.

Figure 3.4 shows three close-up images of the how water reflection and its relationship with the reflected objects is painted. It can be observed that compared with the reflected objects, the reflections are painted with different shades and forms, which does not aim to exactly match how the objects look, but to create a simplified and stylized look.

For the value and tone, the artist creates a variation in lightness and darkness by first layering down a relatively light tone ink and then adding another layer of darker tone ink in some of the regions to express the sense of shadow. In the reflection,



(a)



(b)



(c)

Figure 3.4: Three close-up images of the water reflection in Yang Ming-Yi's paintings [17].

the light tone region is usually painted in a smoother shape compared with the dark tone region. This is because in Chinese ink-and-brush paintings, the light tone ink is mixed with more water and creates smoother shape. On the contrast, the dark tone reflection is usually painted with a high frequency noisy pattern.

For the shape languages in water reflection, Yang Ming-Yi distorts the reflection intentionally in order to create subtle ripple effects on the water surface, which can be observed from the reflection of the vertical boat masks. This also adds a sense of movement and motion into the painting. Another commonly seen visual characteristic in the water reflection is that it usually starts to fade out when the reflected object gets higher and further away from the water surface. This effect can be mostly observed from the reflections for large objects such as buildings.

Another important visual characteristic need to be captured is how the artist paints the connecting area between the reflection and the reflected objects. Figure.3.4 shows two close-up images from Yang Ming-Yi's landscape paintings, in which the architectures fade out into an irregular shape and a non-representative form when getting closer to the water surface. This is an essential characteristic needed to be captured because it is closely related to the "emptiness" philosophy behind Chinese paintings. "In the Chinese perspective, emptiness is not, as one might suppose, something vague or nonexistent. It is dynamic and active." [4] Thus, the emptiness in space and form creates a dynamic relationship between different objects. In Yang Ming-Yi's paintings, for instance, without the emptiness created by the irregular shapes between the buildings and the water surface, the relationship between these two remains rigid and static. With the emptiness as intermediary, the painter creates an active relationship between the human-built architectures and the water from nature. This gives an impression that the buildings could virtually enter the emptiness and melt down into the water, and inversely, the water could rise up into the build-

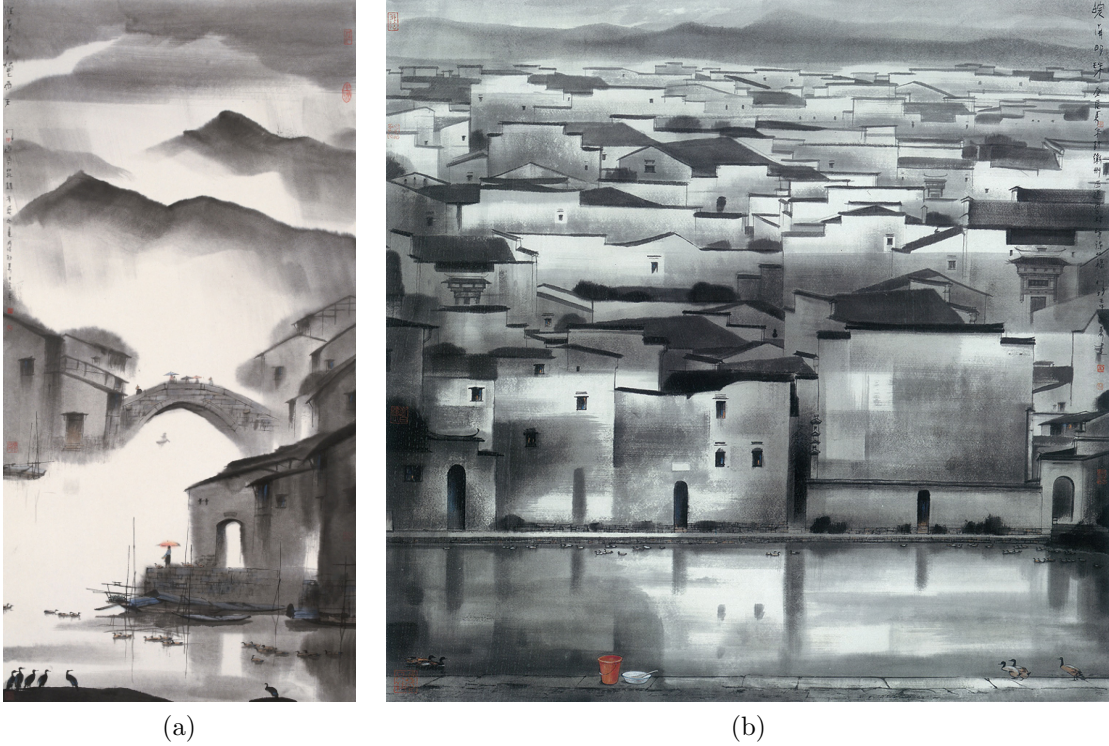


Figure 3.5: Two examples from Yang Ming-Yi’s paintings, in which multi-point perspective aesthetics is used in composition [16].

ings. As a result, buildings and water are no longer perceived as static elements that stands against each other, but as representation of the dynamic law of the nature.

3.1.4 *Layout and Composition*

In this section, we analyze the painting references based on the artistic aspect of layout and composition, which refers to how the artist arranges composition of foreground, midground and background elements harmoniously in the aesthetics of Chinese ink-and-brush paintings.

The perspective in Chinese paintings is very different from what western painting has. It uses multi-point perspective, instead of one-point perspective [29]. This unique characteristic influences the layout and composition of foreground, midground

and background elements in Chinese landscape paintings. Multi-point perspective does not presume a privileged vanish point. Background objects behind other objects may be painted in full view. “This creates the effect that the painter is moving across the scene, merging himself into a dynamic space and contemplating things from far away, nearby and different sides [4].” In Yang Ming-Yi’s paintings, multi-point perspective aesthetics can be observed by analyzing the way he arranges foreground, midground and background elements. In Figure 3.5(a), the building sets with the bridge are painted higher in vertical direction compared with the foreground buildings with the female figure holding a red umbrella, even if in physical world they should be sitting on the same plane. Figure 3.5(b) shows another more extreme example of multi-point perspective, in which as the buildings move away from the viewers, they are rising up in vertically in layout. However, in the virtual 3D space in CG, one virtual camera with a fixed one-point perspective is usually used to render the image. So a solution needs to be figured out in order to match the composition aesthetics in Chinese paintings.

3.2 Methodology

In this section, we present a NPR shader for Chinese paintings that supports the essence of the visual and aesthetic characteristics of Chinese paintings as identified in our visual analysis. Our shader gives users artistic controls over the final results through components that provide controls over diffuse shading, weathering, atmospheric and silhouette effects and allow users to change the shape and form. We organize the elements of NPR shader into four categories: (1) Value and Tone, (2) Shape and Form, (3) Water Reflection, (4) Layout and Composition.

3.2.1 NPR Shader for Value and Tone

Our NPR shader provides methods to compute value and tone through diffuse shading with atmospheric and weathering effects.

Let $I = C(x, y)$ denote an image where C is the color of the image at x, y position. Without loss of generality, we treat C as a scalar value in the presentation, which can represents one of the color channels such as red, green and blue. For the sake of simplification of the presentation we usually ignore x, y in the equations.

Since there are mainly five different shades of blacks in Chinese ink-and-brush paintings, our NPR shader mainly produces those shades, which are called Gluey, Thick, Heavy, Thin, Light (see Figure 3.6) [29]. To create shades, we use three shading parameters, which we call diffuse, weathering and atmospheric shading parameters.

To obtain one of these shades of ink for a specific shading point P_S , we use a parameter t_{dw} that is obtained by combining diffuse and weathering parameters. We quantize this parameter to obtain five different levels of blackness. The step function will produce very sharp transition between different shades. To smooth the result and give it a more natural look, a noise function is blended into the transition region by adding the noise on to t_{dw} (see Figure 3.7).

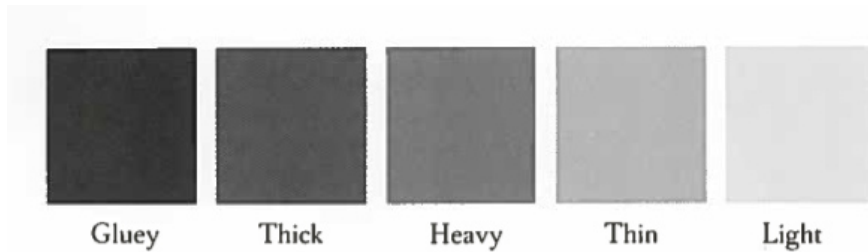


Figure 3.6: The five most common shades of ink in Chinese Paintings [29].

$$C_d = \begin{cases} C_1 & \text{if } (t_{dw} + noise) \leq t_1 \\ C_2 & \text{if } t_1 < (t_{dw} + noise) \leq t_2 \\ C_3 & \text{if } t_2 < (t_{dw} + noise) \leq t_3 \\ C_4 & \text{if } t_3 < (t_{dw} + noise) \leq t_4 \\ C_5 & \text{if } (t_{dw} + noise) > t_4 \end{cases}$$

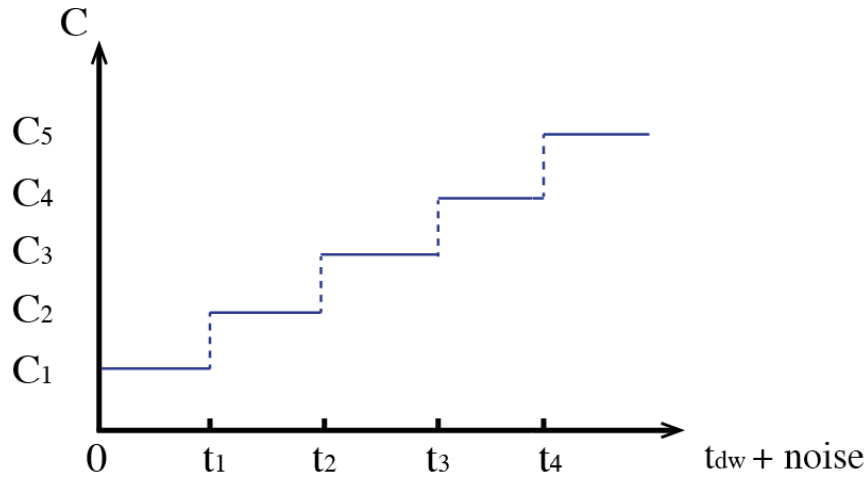


Figure 3.7: The step function used to quantize t_{dw} .

where C_d is the final diffuse color assigned to P_s . C_1, C_2, C_3, C_4, C_5 represent the five different shades of ink. The user has artistic flexibility in controlling the value and tone by changing C_1, C_2, C_3, C_4, C_5 and t_1, t_2, t_3, t_4 (see Figure 3.8).

In the next three subsubsections, we will explain how we compute these diffuse, weathering and atmospheric shading parameters.

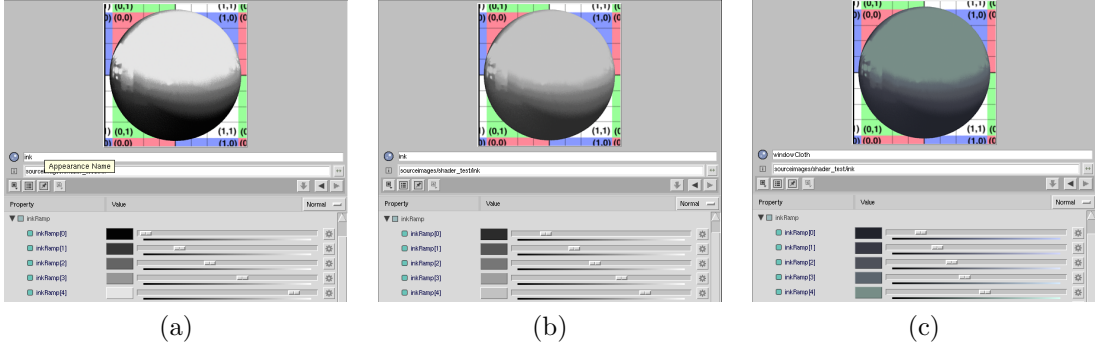


Figure 3.8: Three images showing the ink shaders with different settings in colors.

3.2.1.1 Diffuse Shading Parameters

In order to simulate the effect of painting with different shades of ink, we modify a standard diffuse shader. Our shader uses the standard diffuse parameter t_d for every shading point P_S on a 3D surface. This parameter is computed as (see Figure 3.9):

$$t_d = \vec{N}_S \cdot \vec{N}_{SL}$$

where \vec{N}_S is the surface normal at P_S and \vec{N}_{SL} is the outgoing light ray direction that is computed as:

$$\vec{N}_{SL} = \frac{P_L - P_S}{|P_L - P_S|}$$

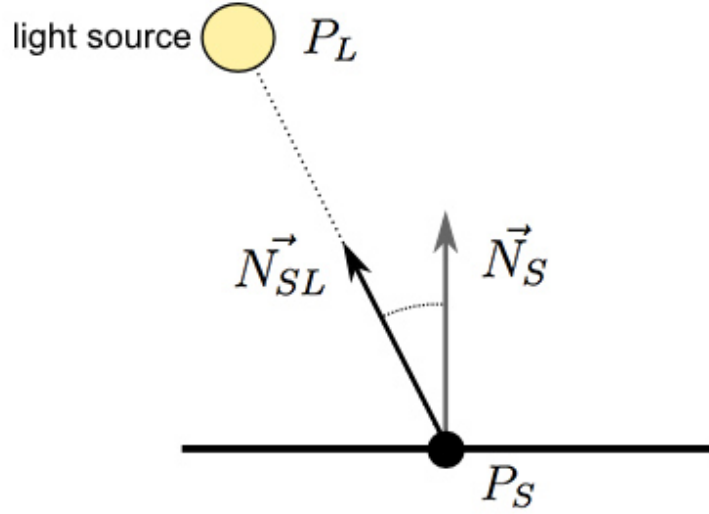


Figure 3.9: An illustration showing the relationship between shading point P_S , light source P_L , surface normal \vec{N}_S and outgoing light ray \vec{N}_{SL} .

where P_L is the position of the light. This is actually the *cosine* of the angle between the vectors \vec{N}_S and \vec{N}_{SL} . The result is a number between -1.0 and 1.0 . The parameter t_d is not directly used in our shader. The negative portion is usually removed by using a clamp function as:

$$\text{clamp}(x) = \begin{cases} 1 & \text{if } x \geq 1 \\ x & \text{if } 0 \leq x < 1 \\ 0 & \text{if } x < 0 \end{cases}$$

This method is useful when we try to simulate how light travels and interacts with a surface in the real world. But this is not our goal for this research and the clamp function creates a flat area when t_d becomes negative. Instead, we use a remap function to remap t_d to the range from 0.0 to 1.0 .

We define our remap function as (see Figure 3.10):

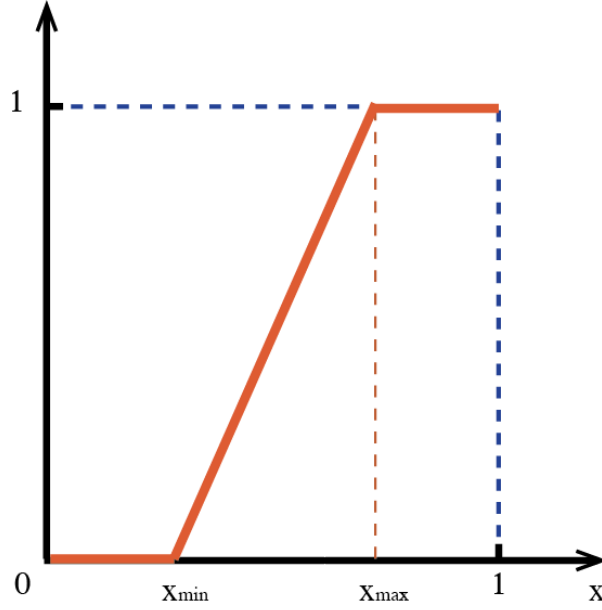


Figure 3.10: Remap function

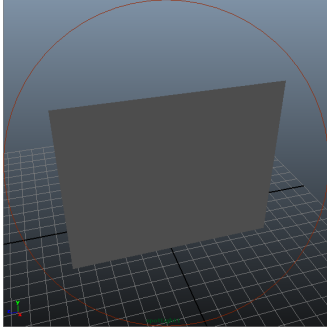
$$remap(x, x_{max}, x_{min}) = clamp(\frac{x - x_{min}}{x_{max} - x_{min}})$$

In this case, we use $remap(t_d, -1, 1)$ to adjust our diffuse shading parameter t_d .

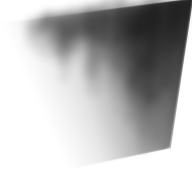
3.2.1.2 Adding Weathering Shading Parameter

The weathering shading parameter t_w is created by using a grey-scale texture map, in which the black and dark part indicates where the weathering effect happens.

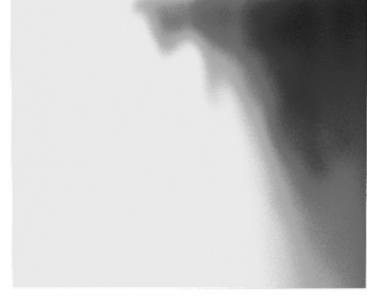
Figure 3.11 shows an example of using a projection texture map on a plane to create the weathering parameter t_w . Figure 3.11(a) shows a screenshot of the projection angle. Figure 3.11(b) shows the grey-scale texture map and Figure 3.11(c) shows the render result of how t_w creates a gradient and variation between different levels of blackness, which represent different shades of ink in Chinese painting.



(a) Projection angle of the texture map.



(b) The texture map being projected.



(c) The render result of how t_w effects the value and tone of the surface.

Figure 3.11: An example of applying our weathering shading parameter t_w on a plane by using projection texture map.

And then we combine the diffuse and weathering shading parameters together:

$$t_{dw} = t_d \otimes t_w$$

where \otimes stands for one of the operations below:

(1) Multiply

$$t_{dw} = t_d t_w$$

(2) Take the minimum of two values

$$t_{dw} = \min(t_d, t_w)$$

(3) Mix

$$t_{dw} = \text{clamp}(t_d + t_w - 1)$$

In our implementation, we use the mix option because it gives us a better artistic



(a) The result with only t_d .

(b) The result with the combination of t_d and t_w .

Figure 3.12: An example of combining t_d and t_w on a 3D teapot model to control the value and tone.

result.

In this way, t_d gives the surface a basic illumination. Then t_w adds the texture details to represent the weathering effects in our reference paintings (see Figure 3.12 and Figure 3.13).

In this way, the artist can easily use t_{dw} to control different levels of blackness on a 3D surface and create detailed texture by painting texture maps to produce the weathering effects.

3.2.1.3 Atmospheric Shading Parameter

To create the depth and atmospheric effect in the reference paintings and have a direct control over the result, a separate ZDepth pass is rendered which contains the atmospheric shading parameter t_a .

In ZDepth pass, we compute t_a as:

$$t_a = 1 - 2 \frac{z_s}{z_{0.5}}$$



(a) The result with only t_d .



(b) The result with the combination of t_d and t_w .

Figure 3.13: An example of combining t_d and t_w on our building models in the final animation to control the value and tone.

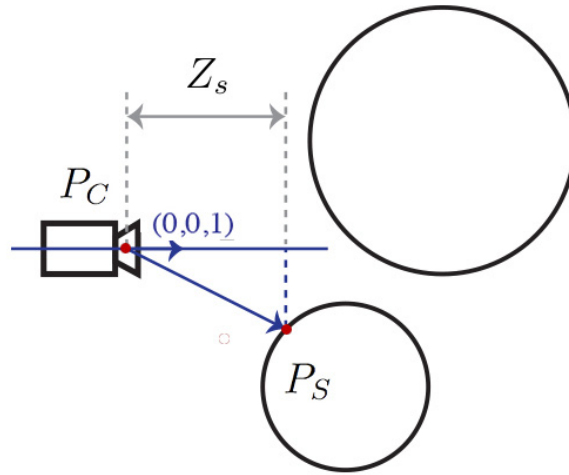
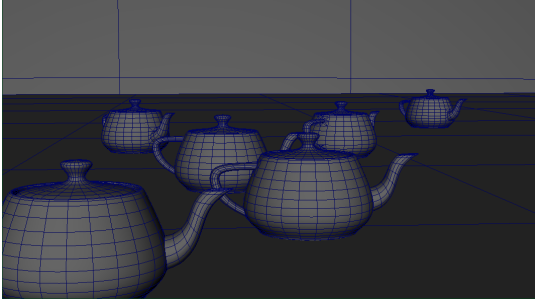


Figure 3.14: An illustration showing how z_s is computed in 3D space.



(a) A screenshot of the 3D scene.



(b) How the ZDepth pass looks.

Figure 3.15: A ZDepth pass example for a specific 3D scene.

where $z_{0.5}$ is a custom float value provided by the user, which controls the distance where t_a becomes 0.5. And z_s is the distance between a specific shading point P_S and the camera in the Z axis of the camera, which is computed as:

$$z_s = (0, 0, 1) \cdot (P_S - P_C)$$

where P_S is the location of the current shading point. P_C is the location of the virtual camera from which we render the scene. and $(0, 0, 1)$ is a unit vector facing Z axis of the camera (see Figure 3.14).

When P_S is close to the camera, z_s is small. In this case, $2^{-\frac{z_s}{z_{0.5}}}$ is a number close to 1 and is equal to 1 when z_s gets to 0. In other words, t_a becomes a small positive number around 0 when P_S is close to the camera. When P_S moves further away from the the camera, z_s gets bigger and $2^{-\frac{z_s}{z_{0.5}}}$ becomes smaller. In this case, t_a gets bigger and can go as big as to 1 (see Figure 3.15).

Based on Section 3.1, the objects in atmospheric effects are usually painted in a lighter tone and have less contrast. Therefore, we create an image $I_a = C_a(x, y)$ with less contrast and lighter tone, which can be obtained by applying a color correction function the original diffuse image I_d (see Figure 3.16):

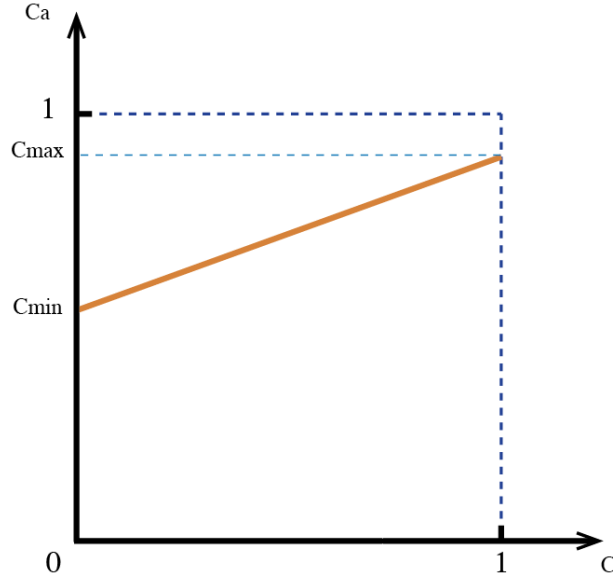


Figure 3.16: The color correction function for creating I_a .

$$C_a(x, y) = \text{clamp}(C_{\min}(1 - C_d(x, y)) + C_{\max}C_d(x, y))$$

where C_{\min} and C_{\max} are two custom values controlled by the user to specify the darkest and brightest color of the image. Figure 3.17 shows how we can change the original image I_d into the atmospheric effects image I_a by using the function above.

And then, we mix I_d and I_a together based on the atmospheric parameter t_a

We define our mix function as:

$$\text{mix}(x, y, a) = (1 - a)x + ay$$

where a is a value between 0.0 and 1.0, which controls the percentage of x and y in the result.

In this way, we can compute the final color as:



Figure 3.17: A comparison between the original diffuse image I_d and the atmospheric effects image I_a .

$$C_f(x, y) = (C_d(x, y), C_a(x, y), t_a(x, y))$$

Where C_f is the color of the final image I_f after adding the atmospheric effects.

Instead of using t_a directly, we apply the remap function defined in Section 3.2.1.1 on t_a :

$$t_a \leftarrow \text{remap}(t_a, t_{min}, t_{max})$$

where $0 < t_{min} < t_{max} < 1$. The purpose of this computation is to make t_a become 0 in some of the foreground regions and make it become 1 in some of the background regions (see Figure 3.18).

And then we use the new t_a to mix I_d and I_a together. In this way, atmospheric effects will only effects the objects in the background (see Figure 3.19).

3.2.2 Create the Irregularities in Shape and Form

In this section, we discuss how to capture the irregularities in shape and form commonly seen in Chinese paintings. We propose three shading parameters to achieve the result, which we call silhouette opacity mask parameter, edge displacement pa-



(a) Original t_a .



(b) t_a after the remap computation.

Figure 3.18: Our atmospheric shading parameter t_a before and after the remap computation.



Figure 3.19: Final result by mixing I_d and I_a together.

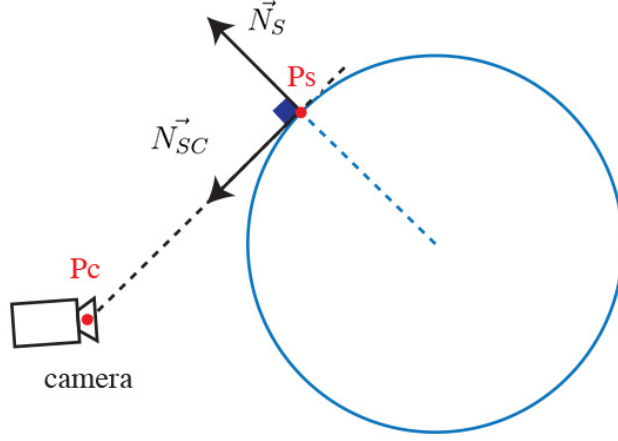


Figure 3.20: How surface normal and camera ray are used for silhouette edge detection.

parameter and outline parameter.

We use silhouette opacity mask parameter t_{se} and edge displacement parameter t_{sd} to break the perfectly smooth edges on a 3D mesh, and use outline parameter t_o to add the dark outlines on edges to match the reference paintings. In the next three subsections, we will explain how we compute these three parameters.

3.2.2.1 Silhouette Opacity Mask Parameter

To achieve the irregularities in the edge regions, we introduce the silhouette opacity mask parameter t_{se} to make the silhouette edges of a 3D mesh partially transparent. This method was proposed by Clara Chan in 2002 [3].

The outline or silhouette of a 3D object can be defined as the set of points on the objects surface whose surface normal is perpendicular to the camera ray, which is represented as a vector starting from the viewpoint to the surface point [10](See Figure 3.20). So, for a specific visible shading point P_S , the silhouette edge parameter t_{se} can be computed as:

$$t_{se} = \vec{N}_S \cdot \vec{N}_{SC}$$

where \vec{N}_{SC} is the outgoing camera ray, which can be computed as:

$$\vec{N}_{SC} = \frac{P_C - P_S}{|P_C - P_S|}$$

P_S will be considered inside the silhouette edges of a 3D mesh if $t_{se} = 0$. However, this condition is too strict and does not have any control over the width of the silhouette edges. Therefore, two parameters, δ_0 and δ_1 , are brought into the equation to give the user more controls. The silhouette edge parameter t_{se} is then modified by using the remap function as:

$$t_{se} \leftarrow \text{remap}(t_{se}, \delta_0, \delta_1)$$

Note that since we only calculate the visible shading point, t_{se} will not be negative. To make the silhouette edge region appear irregular, instead of directly use t_{se} , we blend a noise function into the parameter (see Figure 3.21):

$$t_{se_n} = t_{se} + s_{se} \text{noise}(\omega_{se})$$

where s_{se} and ω_{se} are two custom values controlled by the user to change the scale and frequency of the noise.

Then, we multiply t_{se_n} with the opacity of the ink shader to make it partially transparent on the silhouette edges. By adjusting δ_0 , δ_1 and ω_{se} , the user can control how irregular the silhouette edges look (see Figure 3.22).

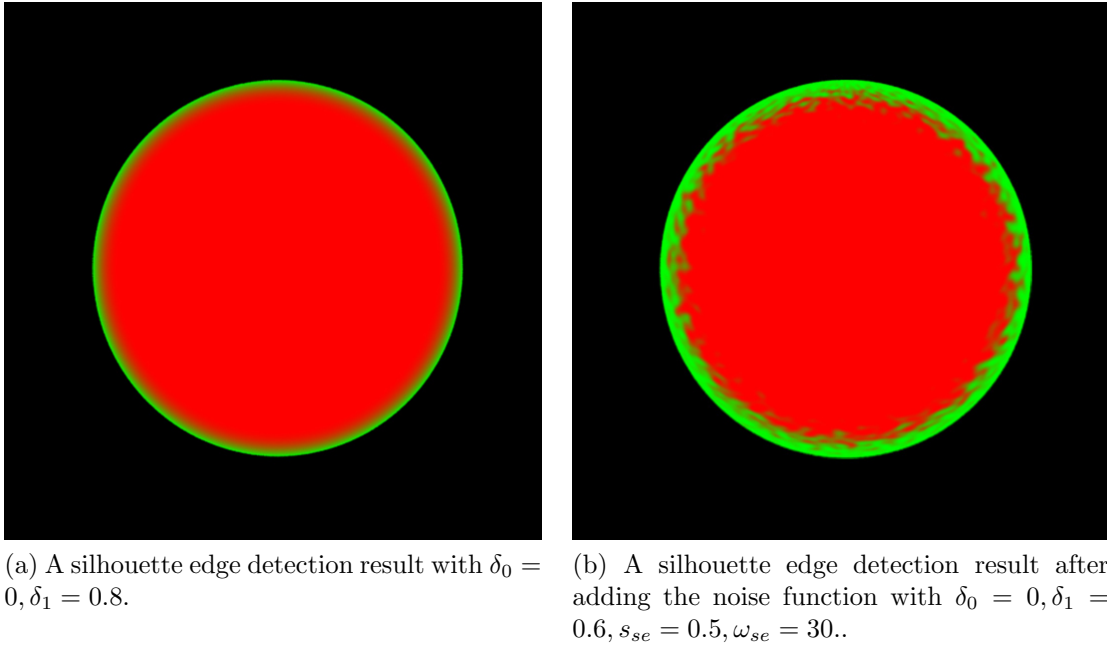


Figure 3.21: The silhouette edge detection results before and after adding noise.

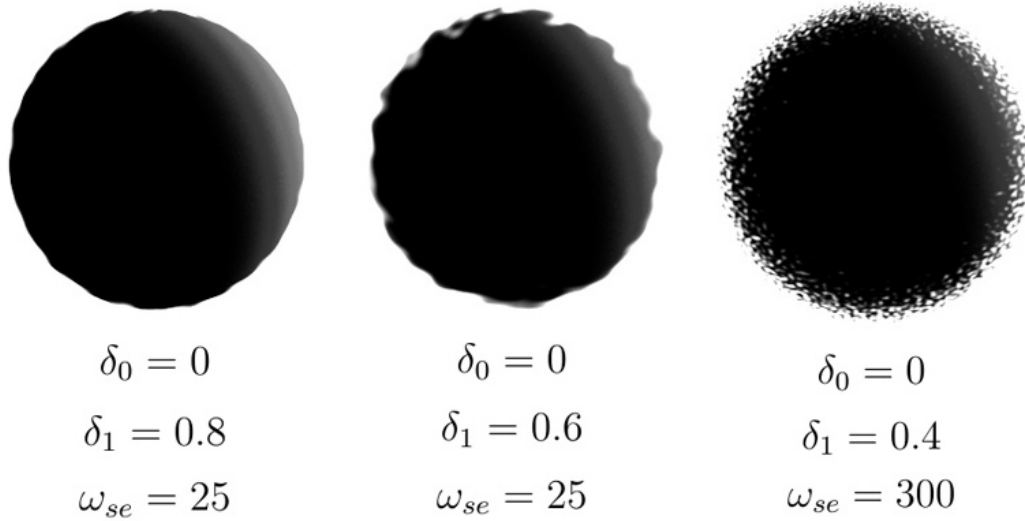


Figure 3.22: Several images which show how δ_0 , δ_1 and ω_{se} can be used to create different irregular patterns in the silhouette edges.

3.2.2.2 Edge Displacement Parameter

In addition to the silhouette opacity mask parameter, we also add a custom displacement shader to the 3D mesh to break the perfectly smooth edges.

A displacement shader alters the smoothness of a surface by effecting the geometry of the surface. We use parameter t_{sd} to control the amount of distortion the displacement shader creates on a specific shading point P_S . Depends on whether t_{sd} is a positive or negative value, the surface will get pulled up or pushed down along the surface normal direction. If t_{sd} is 0, the surface remains the same. A noise function is used to generate the pattern of the displacement. Since we only want the displacement appears in the edge regions of a 3D mesh, we introduce an edge parameter t_{de} to control where the displacement appears.

$$t_{sd} = t_{de}(s_{sd}noise(\omega_{sd}) + \sigma_{sd})$$

where s_{sd} , ω_{sd} and σ_{sd} are the scale, frequency and offset of the noise function which can be provided by the user.

t_{de} is the edge parameter that is computed using the silhouette edge parameter t_{se} from Section 3.2.2.1, in this case, as:

$$t_{de} = 1 - t_{se}$$

Note that t_{de} can only take values between 0.0 and 1.0, which serves as a mask to multiply with the displacement scale value. $t_{de} = 0$ means that there is no displacement happens in that region, $t_{de} = 1$ means that displacement happens in full scale and if t_{de} yields a result between 0.0 and 1.0, it will give the surface a scaled down displacement which helps smoothly connect the fully displaced and non-



Figure 3.23: A series of images which show how partial displacement and transparency mask are used to create irregularities.

displaced region. In other words, t_{de} makes the displacement only appear within the silhouette edges.

In Figure 3.23, the left image shows a render result of a 3D sphere without any displacement. The middle image shows the result after adding the edge displacement parameter t_{sd} and the right image shows how the sphere looks like after adding the silhouette opacity mask parameter t_{se} .

Figure 3.23 shows how we can combine t_{se} and t_{de} to create irregular silhouette edges on the 3D mesh. The benefit of combining both methods is that it can create discontinuity in the noise pattern, which cannot be achieved solely by the displacement parameter t_{de} . And it can also make the irregular pattern go beyond the boundary of the 3D mesh, which is not possible to achieve only using the silhouette edge opacity parameter t_{se} . Figure 3.24 shows the render result of the 3D teapot model after we combine t_{se} and t_{de} .

The edge distortion can be achieved in silhouette edge regions for curved surfaces using the method above. However, the method does not apply to a 3D mesh which is mainly made up of flat surfaces like a cube. This is because for a flat surface, surface

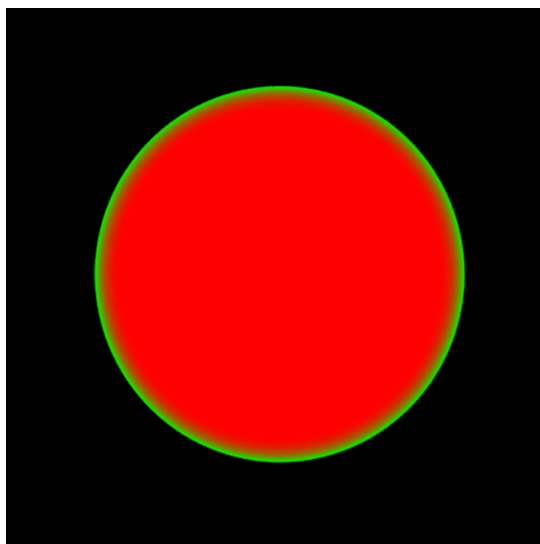


(a)

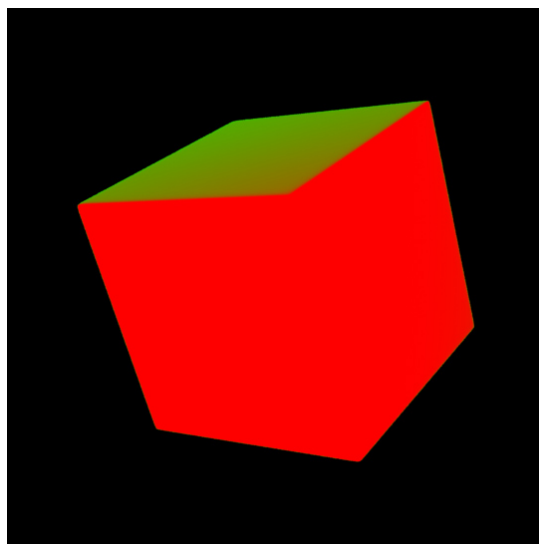


(b)

Figure 3.24: An example of applying t_{se} and t_{sd} on a 3D teapot to break the perfectly smooth edges.



(a)



(b)

Figure 3.25: Two images showing the edge detection results on a sphere and a cube using the same silhouette edge detection algorithm.

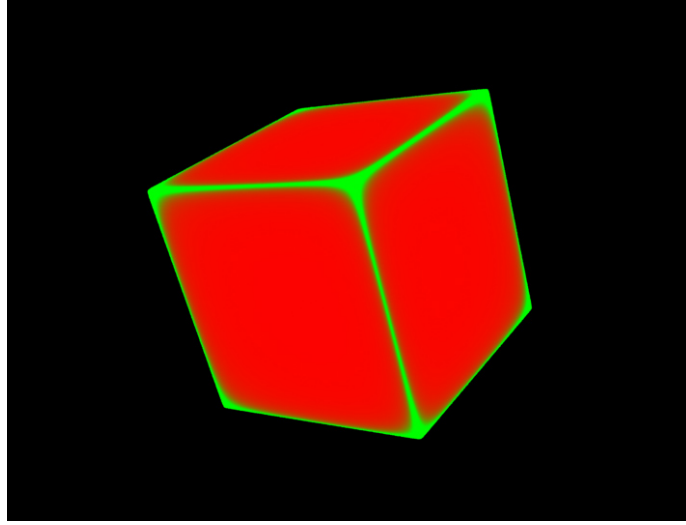


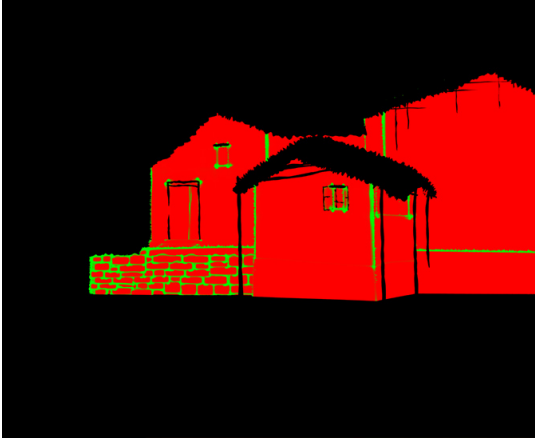
Figure 3.26: The result of using a painted texture map for a cube model to mark where the edge regions are.

normal \vec{N}_S stays the same. When t_{se} is used for edge detection, a very large region will be detected as ‘edge’ instead of a thin region in the silhouette (see Figure 3.25).

To solve this problem, we use a painted texture map to create the edge parameter t_{de} on cubic objects (see Figure 3.26). This method works on cubic objects because the location of the edges will not change based on the viewing angle.

By using a painted texture map as t_{de} to control where the displacement happen on cubic meshes, we can break the perfectly smooth edges on the objects (see Figure 3.27).

We observe that there are usually two types of edge displacements: one is in low frequency and another in high frequency. Their amplitude are almost the same. The low frequency component comes from the imperfections in brush motion and high frequency component comes from the ink diffusion effects on rice paper. Now, let I_h and I_l denote edge displaced images in high and low frequency respectively. In other words, I_h is created by using an ω_{sd} , that is larger than ω_{sd} used to create I_l . This



(a) t_{de} on our building models by using texture maps.



(b) The result of applying t_{sd} on the building model controlled by t_{de} .

Figure 3.27: An example of applying edge displacement parameter t_{sd} based on the edge parameter t_{de} created by texture maps.

guarantees that the boundary edges in I_h has a higher frequency than the boundary edges of I_l as shown in Figure 3.28. The overall displacement is simply a mixture of these two images with two different edge displacements as:

$$I_{sd} = \text{mix}(I_h, I_l, a)$$

where I_{sd} denote final edge displaced image which is the mixture of two types of edge displacement. One additional issue is that the edges in this image are too sharp. To make the resulting edges look similar to edges in Chinese paintings, we further need to smooth the displacements only in edge regions. This operation is obtained by mixing the original images edges, I_{sd} , with a blurred image, $\text{Blur}(I_{sd}) = \tilde{I}_{sd}$, only at the edge regions using the edge parameter t_{de} as (see Figure 3.28 and Figure 3.29):

$$C_{smooth}(x, y) = \text{mix}(C_{sd}(x, y), \tilde{C}_{sd}, t_{de}(x, y))$$



(a) I_l : The image with low frequency edges



(b) I_h : The image with high frequency edges.



(c) I_{sd} : The mix result of I_h and I_l .



(d) I_{smooth} : The blur result of applying a blur filter only in edge region.

Figure 3.28: Examples of Images with high and low frequency boundary edges. As it can be seen from these examples, the low frequency edges are introduced by brush movement —on purpose or unsteady of hands of artists— and high frequency edges comes from ink diffusion effects on the paper.



(a) Close-up of I_l



(b) Close-up of I_h



(c) Close-up of I_{sd}



(d) Close-up of I_{smooth}

Figure 3.29: Close-up details of how edges in I_h , I_l , I_{sd} , I_{smooth} look like.

where $\tilde{I}_{sd} = \tilde{C}_{sd}(x, y)$ and I_{smooth} denote final image and $I_{smooth} = C_{smooth}(x, y)$. In the equation, we explicitly show x and y since t_{de} is not the same for all pixels.

3.2.2.3 Edge Detection for Creating the Dark Outline Effect

In Chinese paintings, artists sometimes draw outlines to finalize the shape as we have discussed in visual analysis. Previous section mentions the limitation of using silhouette edge detection algorithm and why this method only works on certain types of meshes (see Figure 3.25). Therefore, the outlines we have obtained earlier with silhouette edges does not provide sufficient user control for drawing outlines. To solve this problem, we introduce a new outline parameter t_o , which is obtained directly from normal map. This parameter as other parameters before gives us a float value between 0.0 and 1.0. To create the dark outlines as discussed in the visual analysis, we multiply this new parameter t_o with I_{smooth} image as:

$$C_o(x, y) = C_{smooth}(x, y)t_o(x, y)$$

To obtain the new parameter t_o , it is easy to observe that outlines basically happen on the connection regions between two surfaces whose surface normals are facing to dramatically different directions (see Figure 3.30).

Based on this observation, t_o can be obtained by detecting edges of the normal map. Let I_{NC} denote the normal map for a 3D model, which contains the surface normal information at each shading point and represents it as a color. So an abrupt change in the surface normal can be indicated by an abrupt change in the color of the normal map. And the edges can then be abstracted by using a high-pass filter on the normal map: $HighPass(I_{NC}) = \tilde{I}_{NC}$ (see Figure 3.31).

Usually the edge detection coming out of a high pass filter creates edges that are too thick for our purposes (see Figure 3.32(a)). In order to control the thickness of

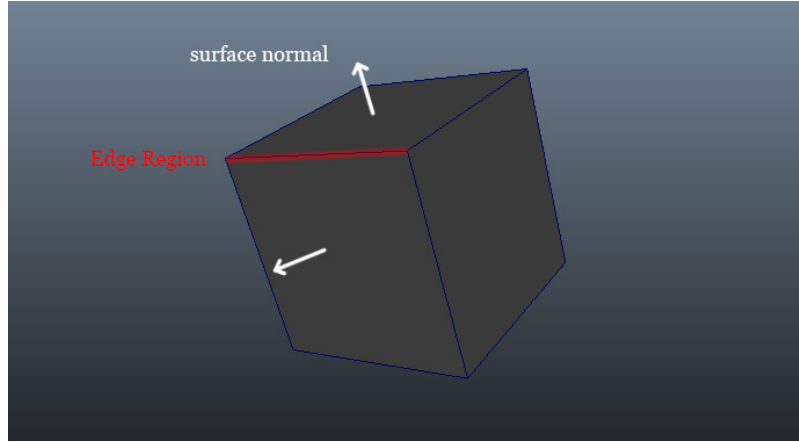
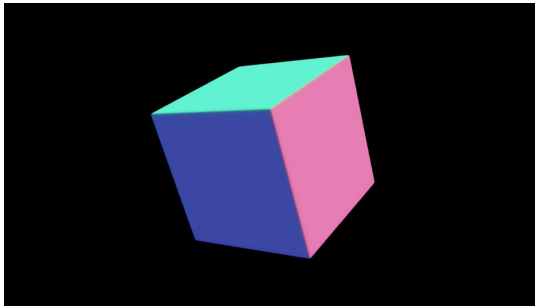
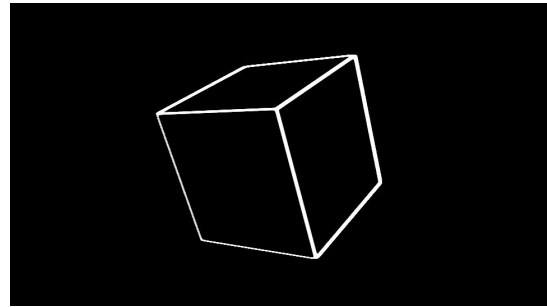


Figure 3.30: An image illustrating where the edge exists on a 3D mesh.



(a) I_{NC} : normal map for a 3D cube.



(b) \tilde{I}_{NC} : result after applying a high-pass filter on the normal map.

Figure 3.31: Two images demonstrating how normal map can be used in edge detection. (a) shows the normal map for a 3D cube. (b) shows the edge detect result by using a high-pass filter on the normal map.

the outline, we use an erosion filter on the edge detection result from the normal map. Erosion makes edges thinner (see Figure 3.32(b)). One problem with using a standard erosion filter is that it creates jagged edges. We, therefore, apply a blur filter onto the image to remove the jagged look. Let I_E denote a black and white image resulted from the edge detection process after applying the erosion and blur operation (see Figure 3.32(c)):

$$I_E = \text{Blur}(\text{Erode}(\tilde{I}_{NC}))$$

our outline parameter can be computed as, where C_E stands for the color information in image I_E (see Figure 3.32(d)):

$$t_o(x, y) = 1 - C_E(x, y)$$

3.2.2.4 Depth-based Property of the Parameters

As we have discussed in visual analysis, some Chinese painters draw the silhouette edges and outlines differently for foreground and background objects. Therefore, in those cases the parameters s_{se}, ω_{se} for the silhouette edge parameter t_{se_n} in Section 3.2.2.1, and s_{sd}, ω_{sd} for the edge displacement parameter t_{sd} in Section 3.2.2.2 must be depth-dependent. For instance, a noise function with a large frequency parameter ω_{sd} may look acceptable in the foreground. But when P_S gets further away to the background, the noise pattern will start to disappear if ω_{sd} is too high.

To introduce depth-dependency, we use atmospheric parameter t_a as:

$$x = \text{mix}(x_f, x_b, t_a)$$

where x stands for either $s_{se}, \omega_{se}, s_{sd}$, or ω_{sd} . x_f and x_b are the parameter values



(a) \tilde{I}_{NC} : edge detect result of a 3D teapot model by applying a high pass filter on the normal map.



(b) $Erode(\tilde{I}_{NC})$: result after using an erosion filter to make the edge thinner.



(c) I_E : result after apply a blur filter to smooth out the result.



(d) t_o : outline parameter.

Figure 3.32: A series of images showing the progress of computing our outline line parameter t_o from the normal map.

for foreground and background, which can be custom values controlled by the user. However, in our case, since the objects in foreground, midground and background are separate and there is no massive camera movement, we can just assign different s_{se}, ω_{se} and s_{sd}, ω_{sd} to different meshes based on their distance to the camera.

3.2.3 NPR Water Reflection

One of our main contributions in this thesis is simulating the effect of water reflection in Chinese paintings. To create the stylized reflection in Chinese ink-and-brush paintings, we introduce five parameters: (1) a light tone reflection image I_{LR} , (2) a dark tone reflection image I_{DR} , (3) a ripple parameter t_{dw} , (4) a reflection mask t_{ra} and (5) a fade-out pattern parameter t_f . In the following subsections, we will discuss how we compute and use these parameters.

3.2.3.1 Creating Light and Dark Tone Reflection

In order to capture the different tones of blackness in the reflection, we create two reflection images with different values and different reflection rays.

For the light tone image I_{LR} , we use a reflective shader which computes the standard reflection ray R for an incoming ray I as (see Figure 3.33):

$$\vec{R} = \vec{I} - 2\vec{N}(\vec{N} \cdot \vec{I})$$

And for the surface being reflected, we use a shader with a lighter tone and lower contrast. This can be done by adjustment $C1, C2, C3, C4, C5$ (see Figure 3.7).

Based on our observation in Section 3.1.3, the water reflections in Yang Ming-Yi's paintings usually have dark high frequency noise patterns in some regions to indicate where the shadow areas exist. Therefore, when rendering the dark tone image I_{DR} , we use a shader with a darker tone and higher contrast on the reflected surface, and

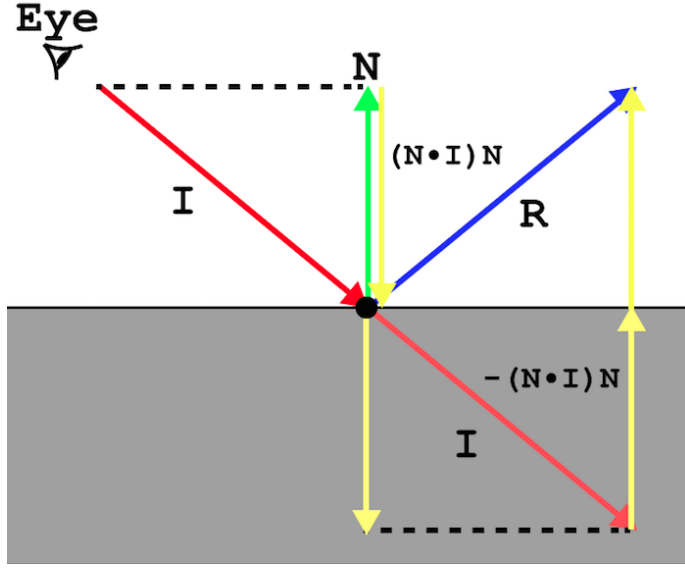


Figure 3.33: How to compute a standard reflection ray R for an incoming ray I .

offset the standard reflection ray R by multiply a different random value between 0.0 and 1.0 with its x, y, z direction:

$$\vec{R}_N = \vec{R}[0]r_0 + \vec{R}[1]r_1 + \vec{R}[2]r_2$$

where r_0, r_1, r_2 are three different random values between 0.0 and 1.0. This creates a glossy reflection result.

To render the final reflection image, we mix I_{LR} and I_{DR} together:

$$C_{FR} = mix(C_{LR}, C_{DR}, a)$$

where C_{FR}, C_{LR}, C_{DR} are the colors in the final reflection image I_{FR} , the light tone reflection image I_{LR} and the dark tone reflection image I_{DR} . a is an user-defined value used to specify how many percentages of the light and dark tone color we use in the final reflection. Figure 3.34 shows how the light tone and dark tone images

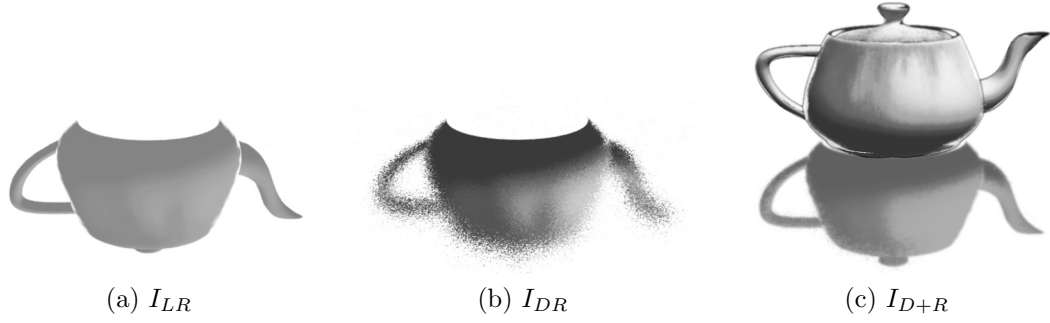


Figure 3.34: A series of images showing the light tone, dark tone and final image with both the object and reflection.

look like.

We then merge the final reflection image with the original image I_d (see Figure 3.34):

$$C_{D+R}(x, y) = \text{mix}(C_{FR}(x, y), C_d(x, y), a_d(x, y))$$

where a_d is the alpha channel of the original image. C_{D+R} is the color information of image I_{D+R} , which has both the object and reflection in it.

3.2.3.2 Animated Ripple Parameter

The water surface model is a flat plane. To create the ripple effects on the water similar to our reference paintings, we apply a displacement shader with an animated ripple parameter t_{dw} onto the water surface.

$$t_{dw} = s_{ndw} \text{noise}(\omega_u + u_o, \omega_v + v_o)$$

where u_o and v_o are two animated parameters based on the current frame number f_c of the animation sequence, which can be computed simply as:

$$u_o = s_u f_c$$

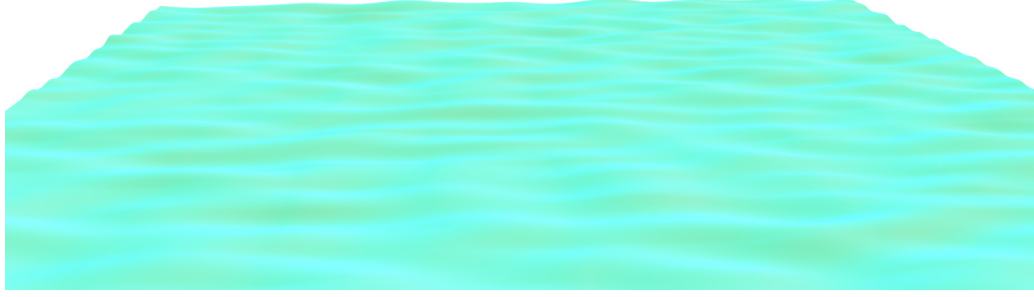


Figure 3.35: Normal map of the water surface plane with the ripple displacement shader.

$$v_o = s_v f_c$$

where s_u and s_v are two custom values that control the speed of the ripple pattern in u and v direction. Figure 3.35 shows the normal map of the water surface plane attached with the ripple displacement shader. And Figure 3.36 shows the new I_{D+R} with our animated ripple parameter.

3.2.3.3 Reflection Mask Parameter

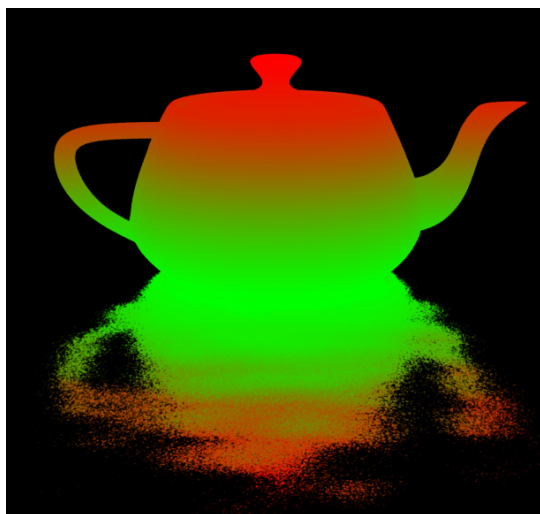
To make the reflection gradually fade out as the object gets further away from the water surface, we attach a special shader onto the reflected object, which indicates the height value of each shading point P_S . The lower the height is, the closer P_S is to the water surface. h is a number between 0.0 and 1.0 which is computed as:

$$h = \text{remap}(y, h_{max}, h_{min})$$

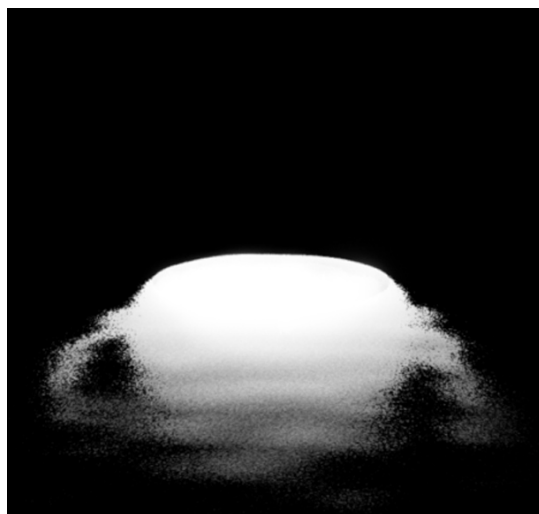
where y stands for the coordinate value in Y axis of the world space. h_{max}, h_{min} are two user-defined values. In Figure 3.37(a), the red channel stands for where $h = 1.0$. And our reflection mask parameter t_{ra} is simply the green channel in the reflection pass of Figure 3.37(a) (see Figure 3.37(b)).



Figure 3.36: The result with our ripple parameter t_{dw} .



(a) The render result by using a shader which indicates the height value by color.



(b) t_{ra}

Figure 3.37: How the reflection mask parameter is obtained.

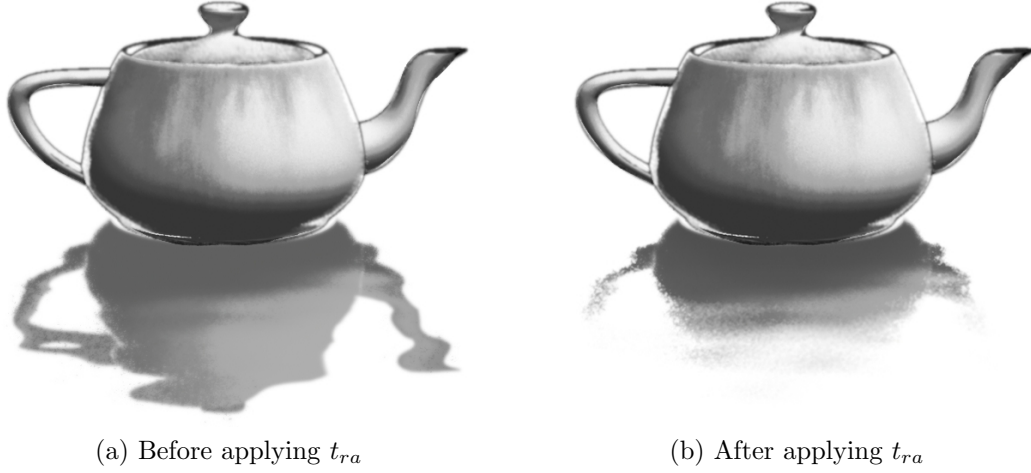


Figure 3.38: Two images showing the result before and after we introduce the reflection mask parameter t_{ra} .

And then we apply t_{ra} as the alpha channel for our reflection pass and combine it with the original image (see Figure 3.38):

$$C_{FR}(x, y) \leftarrow \text{mix}(C_{water}, C_{FR}(x, y), t_{ra}(x, y))$$

$$C_{D+R}(x, y) = \text{mix}(C_{FR}(x, y), C_d(x, y), a_d(x, y))$$

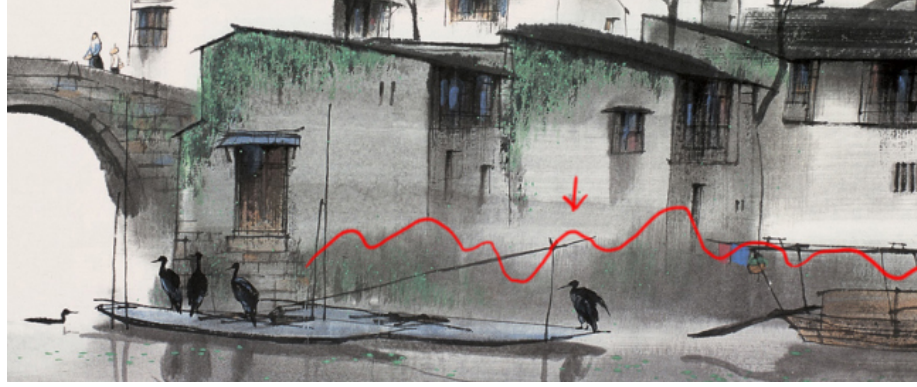
where C_{water} stands for the color of the water surface without any reflection in it. In our case, we use white. Figure 3.38 shows two images comparing the old result without t_{ra} with the new result after we introduce t_{ra} .

3.2.3.4 Fade-Out Parameter

By analyzing the reference paintings in section 3.1, a unique visual aesthetics is abstracted, in which irregular fade-out patterns are used between the architectures and water surface. This helps to blend the objects and the reflections together. With



(a)



(b)

Figure 3.39: Two close-up images of the irregular fade-out patterns painted between the architectures and water from Yang Ming-Yi's landscape paintings. The red draw-over lines illustrate how the patterns are similar to sine functions.

a closer examination of the pattern, it is not hard to find out that the shape is similar to a distorted sine wave function (see Figure 3.39).

Therefore, we use a sine function with noise distortions in both amplitude and frequency to generate the patterns.

$$p_{sine} = s_{tf} noise_2(\omega_3 x_c) \sin(noise(\omega_2 x_c) \omega_1 x_c) + t_{offset}$$

where $0.0 < noise(x) \leq 1.0$, and x_c stands for the coordinate value of a specific

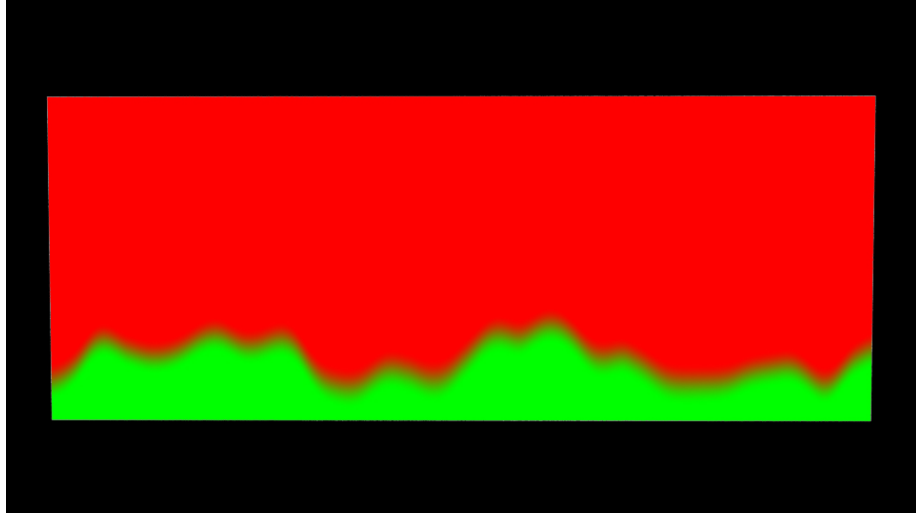


Figure 3.40: A pattern generated from a distorted sine function, which is used to create a similar pattern in Yang’s painting.

shading point P_S in the X axis of the screen or camera space.

Then, we create the fade-out parameter t_f by applying a remap function on the height value y :

$$t_f = \text{remap}(y, p_{sine} + y_o, p_{sine} + y_o)$$

where y_o is an user-defined value which helps to create a transition area around the edges of the patterns. Figure 3.40 is an example showing how this modified sine function can create a pattern similar to the fade-out pattern in our reference paintings. In this render, the green channel stands for where $t_f = 0$ and the red channel stands for where $t_f = 1$.

Figure 3.41 shows the computation result of t_f on a 3D teapot model. And then we mix the render which has both the object and the reflection with a blending color defined by the user:

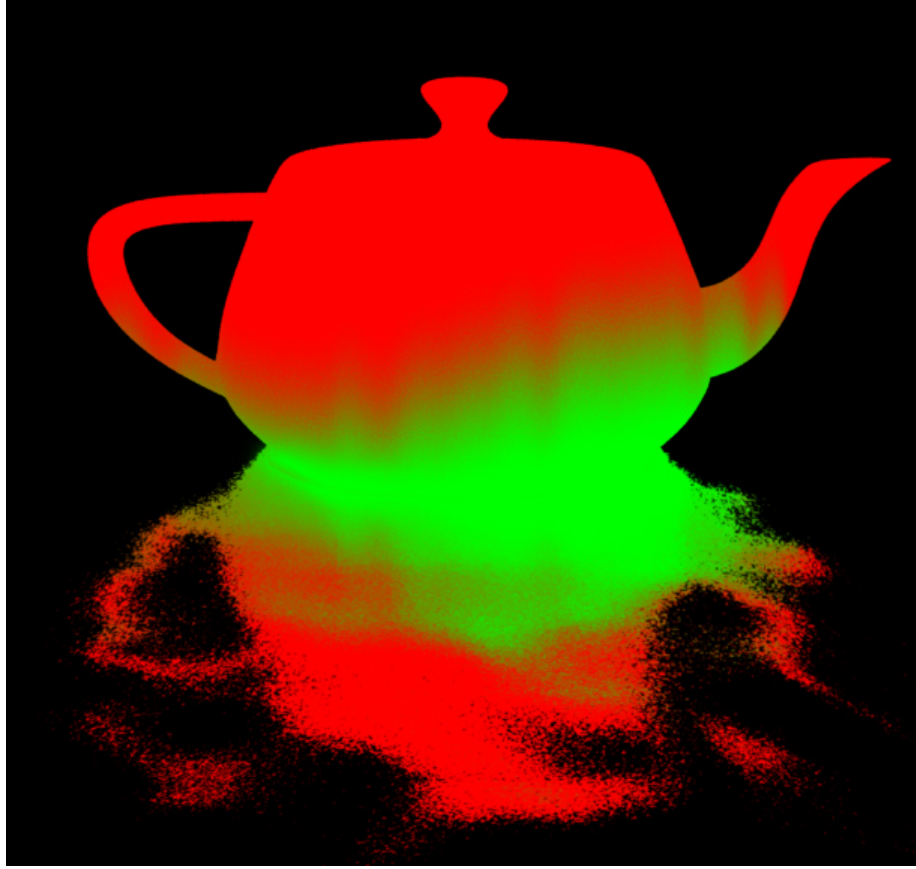


Figure 3.41: A render result of t_f (red channel)

$$C_F(x, y) = \text{mix}(C_{\text{blend}}, C_{D+R}(x, y), t_f(x, y))$$

where C_F is the color information of the final image I_F , C_{blend} is an user-defined color used to blend the object and its reflection together. Since this color can change based on different artistic directions (see Figure 3.39), we use an user-defined color so that the user has more controls over the result. Figure 3.42 shows two results of using different C_{blend} .



(a) I_F with $C_{blend} = (0.9, 0.9, 0.9)$

(b) I_F with $C_{blend} = (0.3, 0.3, 0.3)$

Figure 3.42: Two images showing result with different C_{blend}

3.2.4 Arrange Layout and Composition

In 3D computer graphics, the scene is usually rendered from a virtual camera with one-point perspective. This is because the virtual camera mimics how a camera works in the real world. Thus it is not possible to get the multi-point perspective effect in Chinese paintings from a single virtual camera in 3D.

To solve this problem, we can try creating multiple cameras. But this method does not have enough flexibility and direct control over the final image, because the artist can only see part of the elements from one camera and thus will not have an overall idea of how the final composition looks like. Instead, we render objects in foreground, midground and background into separate images with its own alpha channel. Then, we can apply a translate matrix to each image and merge them back together. In this way, the user can easily re-arrange the layout of the final painting without the constrain of one-point perspective.

4. IMPLEMENTATION AND PROCESS

In this chapter, we talk about how we implement the NPR shading method by using existing graphics softwares, as well as the process of creating the final 3D Chinese landscape painting animation and applying film lighting aesthetics in it. Figure 4.1 illustrates the general process to finish the animation.

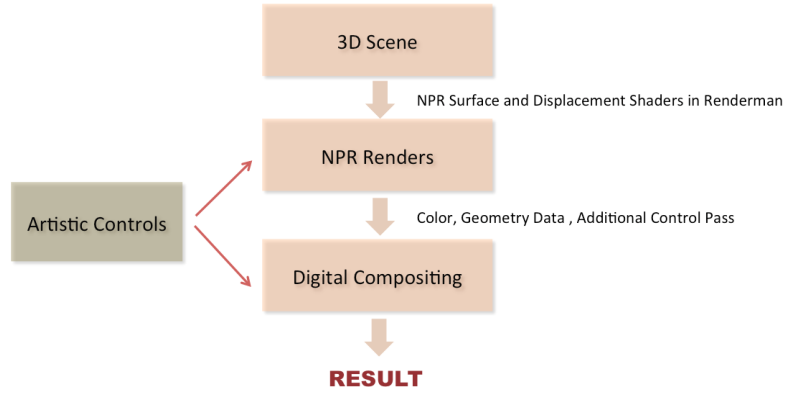


Figure 4.1: An illustration of the general process for creating the final animation.

First a 3D scene is designed and modeled to represent the objects in the landscape painting including buildings, boats, bridges and the water surface. Then, custom NPR surface and displacement shaders are developed in Renderman and attached to the 3D meshes. Virtual CG lights will also be created and used to illuminate the surfaces. The user is able to artistically controls the 3D rendering results by adjusting shader parameters. Then, by using different NPR shaders in different render layers, we can render color information, geometry data and additional control parameters into separate passes. Finally, we bring these passes into a digital compositing software

and assemble them together by using 2D image processing operations. At this stage, the user is also able to put in artistic controls by adjusting the parameters in 2D image processing algorithms.

In this research, we use Autodesk Maya for 3D scene modeling, Pixar’s Renderman for developing NPR shaders, Adobe Photoshop for painting and editing texture maps and The Foundry Nuke for digital compositing.

4.1 Scene Modeling and Development

To create a living Chinese painting in 3D computer graphics based on Yang Ming-Yi’s paintings, we create a concept design which helps us determine what specific elements to be putted into foreground, midground and background.

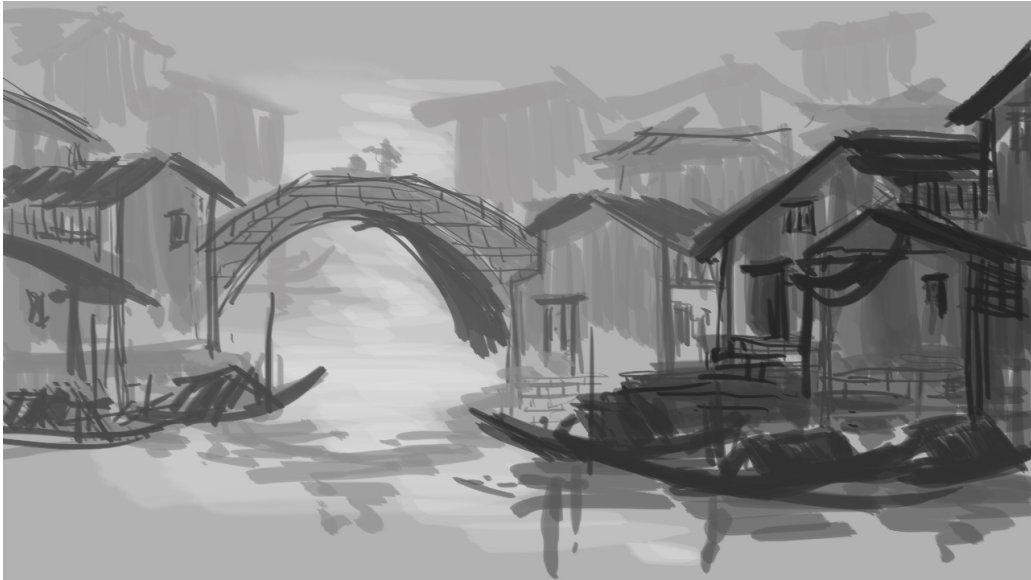


Figure 4.2: Concept design for the final animation.

In the design, we choose some of the most commonly seen subjects in the reference paintings, which include: buildings, boats, bridges and water. Then layout for the

painting was carefully done in a way similar to the reference paintings where plenty of emptiness is left in the design to match the composition aesthetics in Chinese paintings (see Figure 4.2).

3D meshes and a virtual camera are then created in Autodesk Maya using the polygon tool to match the concept design (see Figure 4.3).

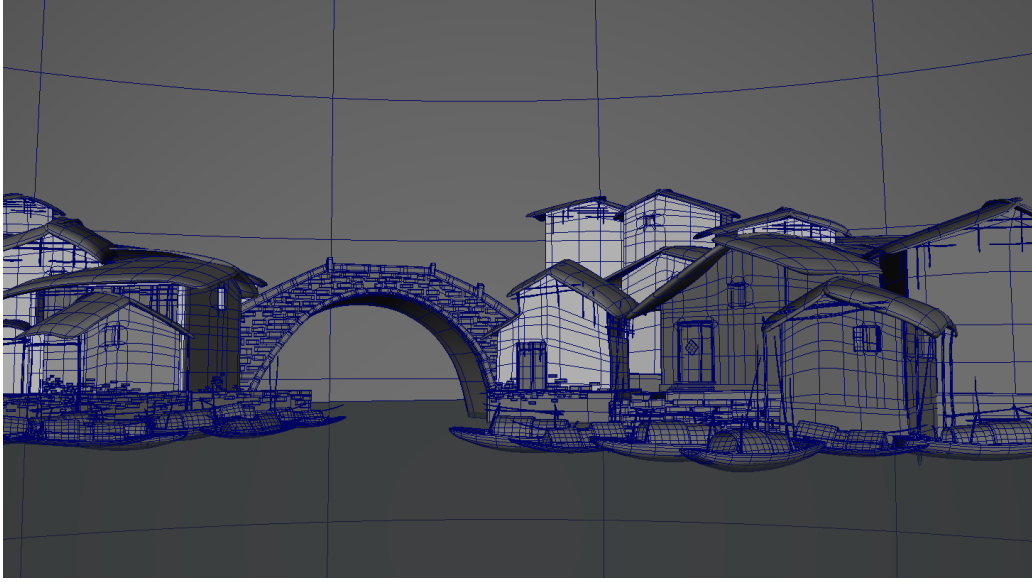
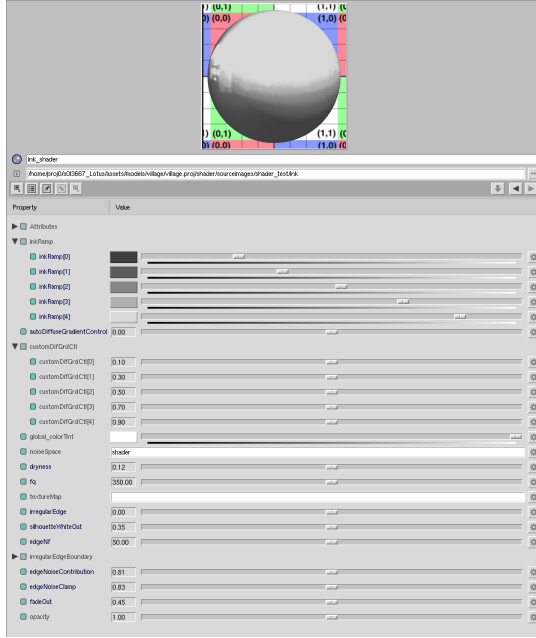


Figure 4.3: Final 3D scene of the landscape Chinese painting.

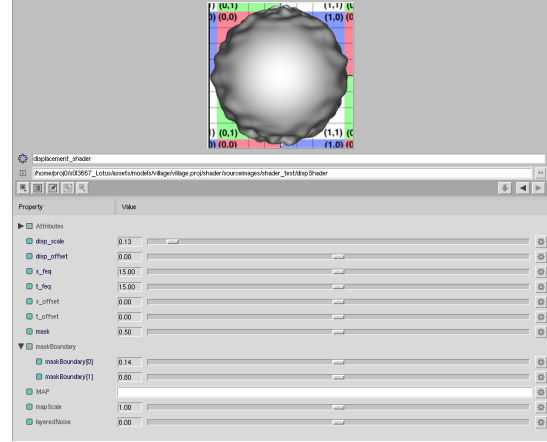
4.2 Create NPR Renders using Renderman

4.2.1 *Create Beauty Pass Render in Renderman*

To create the beauty pass which contains the color information, we develop a procedural ink-shader which computes the surface color and silhouette edge opacity based on our method in Section 3.2. We also create a procedural displacement shader which is able to only distort surface in the edge regions on a 3D mesh. All custom NPR surface shaders and displacement shaders are developed in a C-based



(a) Our custom ink surface shader in Renderman.



(b) Our custom displacement shader in Renderman.

Figure 4.4: Ink surface shader and displacement shader in Renderman.

programming code called Renderman Shading Language (RSL). Figure 4.4 shows the screenshots of how the ink-shader and displacement shader look like in Renderman.

The procedural ink-shader has several parameters for the user to control how the surface looks. They include the controls for specific color representing each different shade of ink, and controls over whether to use an irregular opacity mask in the silhouette edge. Our displacement shader also has custom controls for the user to adjust the frequency and scale of the noise pattern. In this way, we can create different shaders for different objects to match their color and look in our reference paintings.

Figure 4.5 shows an example of how different ink-shaders are created for different elements. The ink-shader for walls uses a high contrast from light to dark across different shades of ink in order to capture the same amount of value contrast between

the light and dark side of the walls in the original paintings. While the roof ink-shader primarily uses very dark tone with an irregular opacity mask in its silhouette edge. And the ink-shader for the door uses a series of brown color ink from light to dark with slight shifts in hue and saturation (see Figure 4.5).

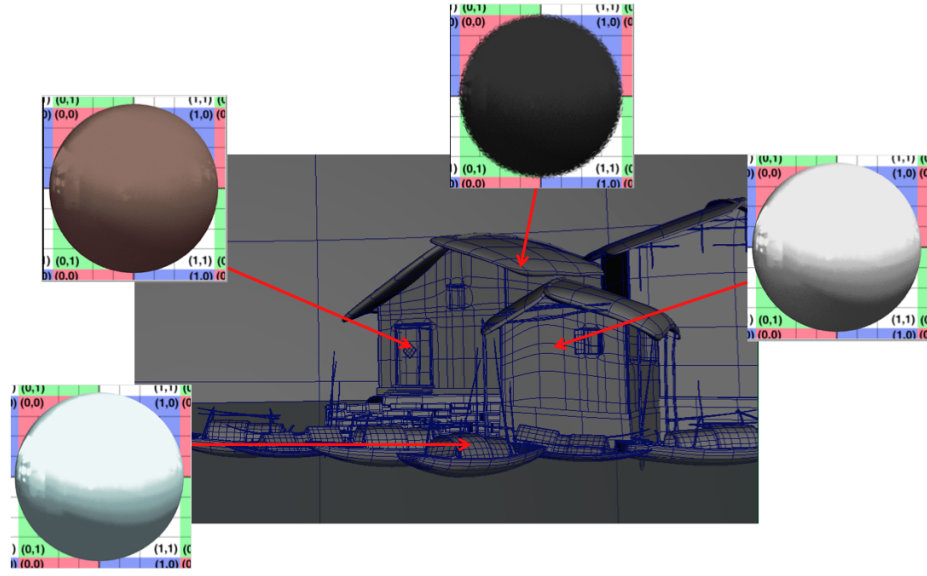
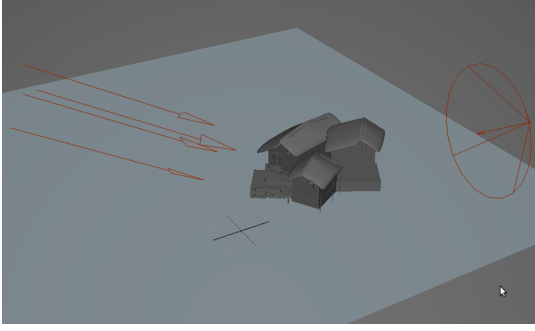


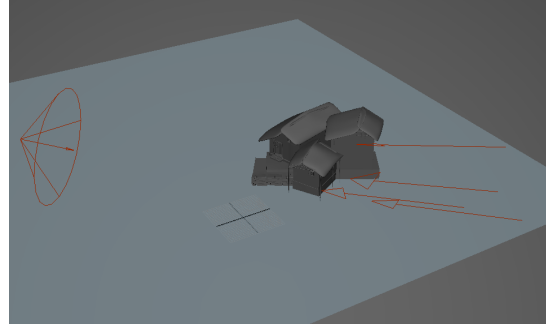
Figure 4.5: Example of assigning different ink-shaders to different surfaces.

After adding the surface shaders to give 3D meshes the basic color, we created several virtual CG lights with different location, direction and intensity to serve as the key and fill lights for the scene. Our surface shader is able to react with these lights based on the diffuse shading parameter t_d . This enables us to change the lighting design by changing the parameters of the virtual CG lights, such as location, direction and intensity.

Figure 4.6(a) and (b) show two different lighting set-up examples, in which a



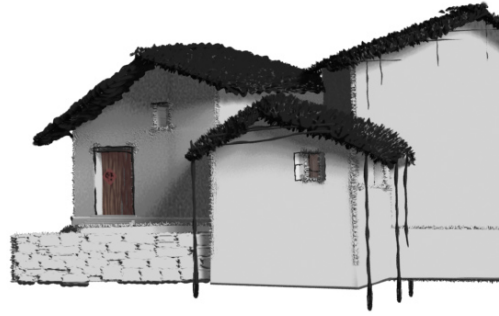
(a) A screenshot from Maya of the lighting set-up one.



(b) A screenshot from Maya of the lighting set-up two.



(c) Render result of the lighting set-up one.



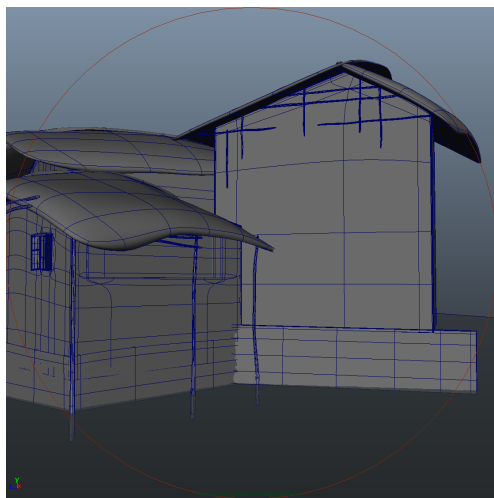
(d) Render result of the lighting set-up two.

Figure 4.6: Result of using different lighting set up in 3D.

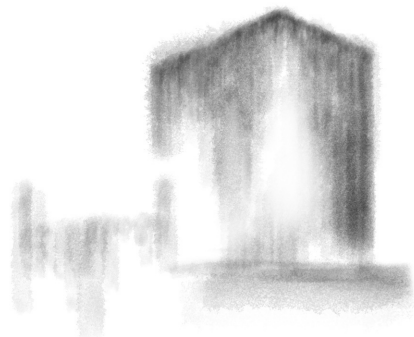
directional light source is used as the key light and a spot light with lower intensity is used as the fill light. Figure 4.6(c) and (d) are the result of how these two different settings.

After finishing the main lighting set-up, we add several projection texture maps used as our weathering shading parameter t_w to create weathering effects details in the texture.

Figure 4.7 shows a projection texture map example. Figure 4.7(a) is the projection angle and Figure 4.7 (b) is the painted texture map. Figure 4.8 shows the new beauty pass after adding the projection textures.



(a) Projection Angle.



(b) Projection Texture.

Figure 4.7: Example of using projection texture maps for weathering shading parameter.

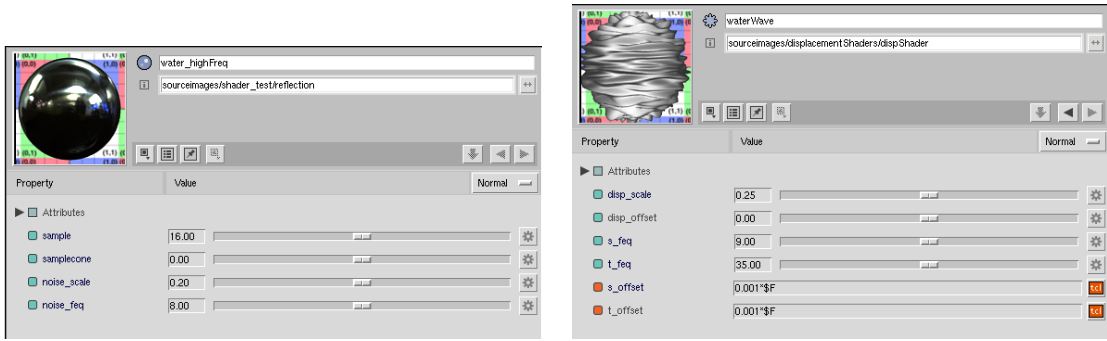


(a) Result by only using virtual CG lights to illuminate the surface.



(b) Result after adding projection texture maps to create weathering effects.

Figure 4.8: The render results of the foreground buildings before and after adding projection texture maps.



(a) A screenshot of how the reflective shader for the water surface looks like in Renderman.

(b) A screenshot of how the displacement shader used to create ripple effects looks like in Renderman.

Figure 4.9: Custom Renderman shaders for the water surface.

4.2.2 Create Light Tone and Dark Tone Reflection

To create the light and dark tone color passes for our reflection, we first create a reflective surface shader and an animated displacement shader for the water surface. The surface shader is a fully reflective shader that computes the surface color solely based on the reflection color. It also has controls over the scale and frequency of the noise value used to offset the reflection ray \vec{R} . In the displacement shader for creating ripple effects, the user is also able to control the scale and frequency of the noise in u, v direction of the texture coordinate. And the user can animate the displacement by using the current frame number variable in tcl expression. Figure 4.9 shows how the reflective surface shader and the animated displacement shader look like in Renderman.

After creating the NPR shaders for our water surface, we use two different ink-shaders for the reflected surface with different tones to render out the light and dark tone reflection images. Figure 4.10 shows how the light and dark tone reflection passes look like.

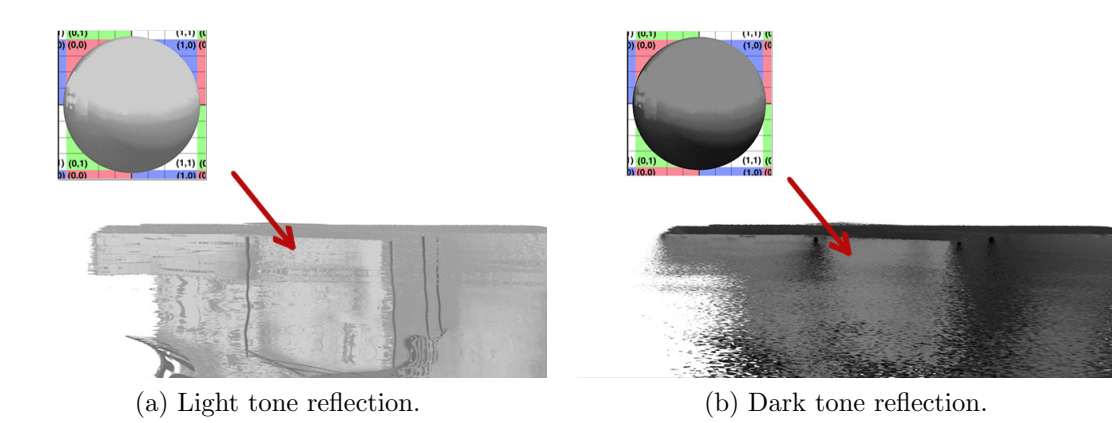


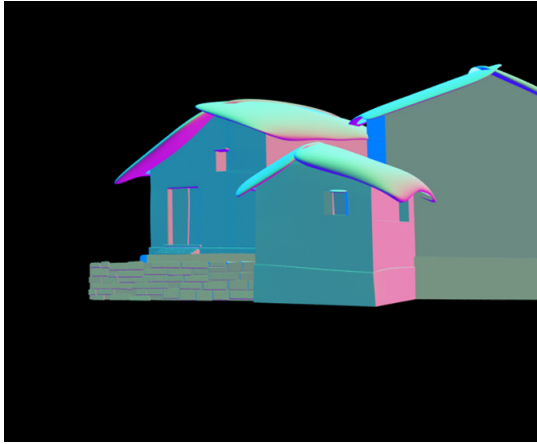
Figure 4.10: Renders of the light and dark tone reflection passes.

4.2.3 Create Control Layers for Digital Compositing

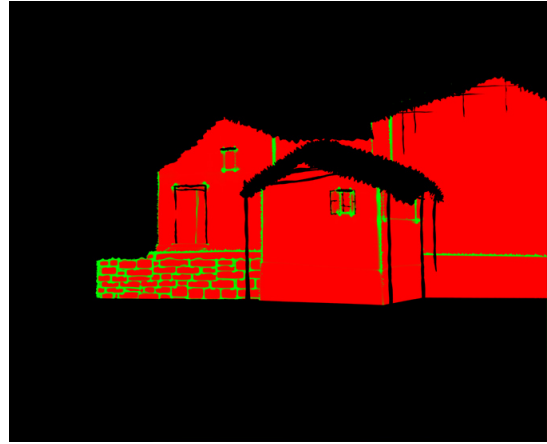
Apart from beauty and reflection passes containing the basic color information, additional passes are also rendered from the 3D scene, which are used to carry other parameters not included in our beauty renders. This process is done by creating different surface shaders in RSL which calculate those parameters and visualize them as color information.

These additional passes include (see Figure 4.11):

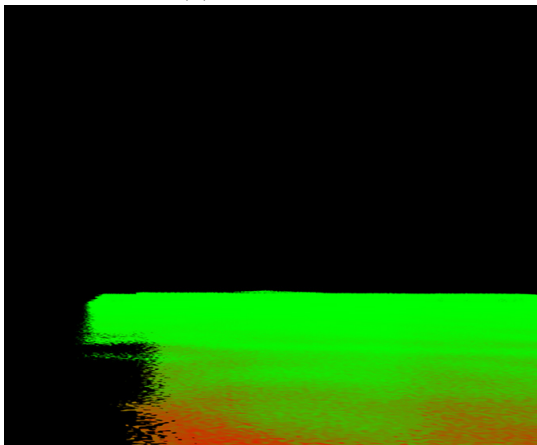
- Normal Map: This pass contains the surface normal information \vec{N}_S .
- Edge Mask: This pass indicates where the edges region exist on 3D meshes. This is our edge parameter t_{de} .
- Reflection Mask: This pass contains the reflection mask parameter t_{ra} and is used to mask out the reflection as the surface getting further away from the water surface.
- Fade-out Pattern: This pass contains the fade out pattern parameter t_f between architecture and the water.



(a) Normal map



(b) Edge mask



(c) Reflection mask



(d) Fade-out pattern

Figure 4.11: Additional control passes for the foreground buildings.

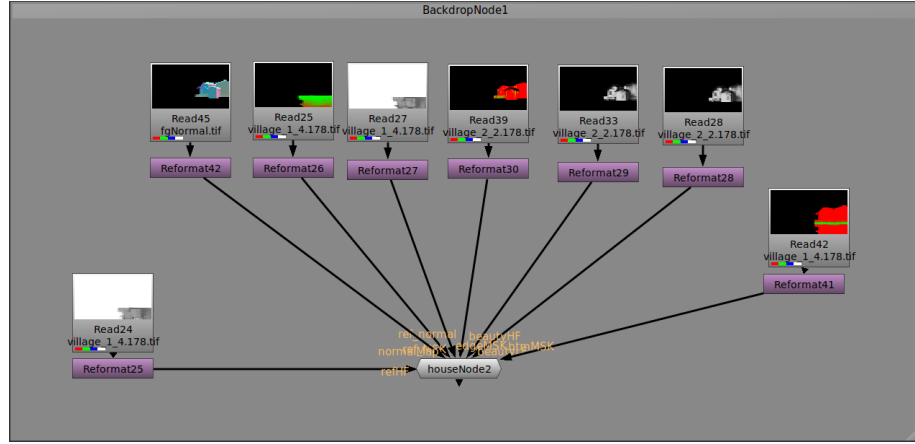


Figure 4.12: A screenshot of how the custom composite node looks like in Nuke.

4.3 Digital Compositing Pipeline

In this section, we are going to discuss the digital compositing pipeline and workflow in Nuke for creating the final animation. It should be noted that we will not discuss the usage or application notes of the software. Therefore, details such as what specific nuke node we use or the meanings of specific parameters in those nodes will not be included in this section nor this paper.

4.3.1 Create Custom Compositing Node to Assemble Different Passes for the Same Element

In digital compositing stage, we first assemble different passes for the same element together. This is done by creating a custom compositing node in Nuke, which is able to take all the render passes as its input and compute one image as the output. The output image contains the final color and alpha data for that specific element (see Figure 4.12).

Inside the custom node, we combine multiple built-in nodes in Nuke which can execute the basic 2D image processing operations mentioned in Section 3. These

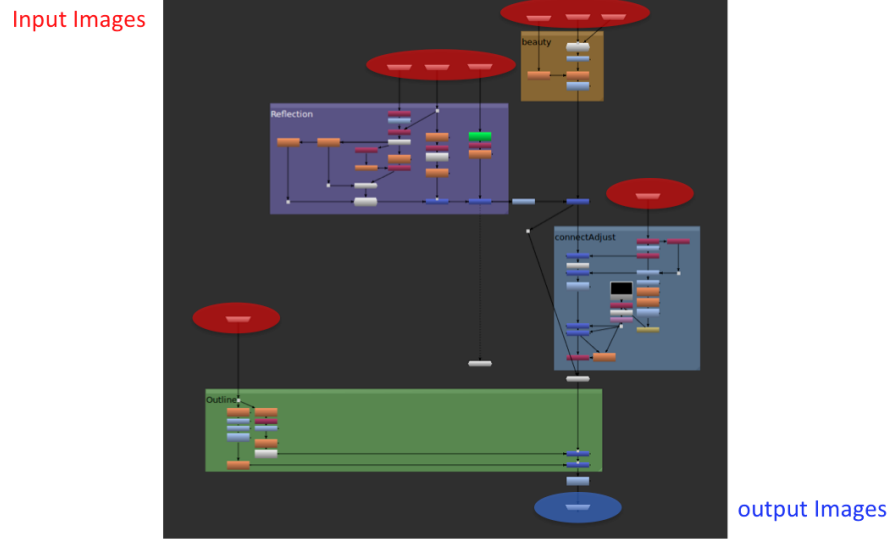


Figure 4.13: The compositing network inside the custom node.

nodes include: a blur node being used as a standard box blur filter, a grade node which acts as the remap function used to adjust the tone of the image, a edge detect node which is used as a high pass filter to extract the edge information for our normal map. These individual nodes are then organized together based on our method and function as one node, which takes in multiple input images as its input (see Figure 4.13). Figure 4.14 shows an example of the color and alpha data of the compositing result for foreground buildings computed by the custom node.

4.3.2 Merge Different Elements Together to Create the Final Painting

After creating the custom compositing node, we can use it to assemble different passes together for each element. In this way, we can obtain the compositing result for each element in the painting, which contains its color and alpha data. Figure 4.14 shows the compositing result for our foreground building. Figure 4.15 shows another compositing example for the foreground boats.



(a) Color information for the foreground buildings.

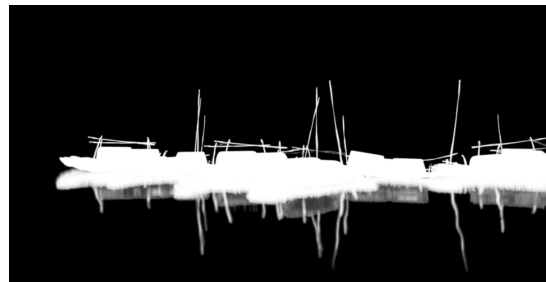


(b) Alpha channel for the foreground buildings.

Figure 4.14: The compositing result of the foreground buildings.



(a) Color information for the foreground boats.



(b) Alpha channel for the foreground boats.

Figure 4.15: A compositing result of the foreground boats.



Figure 4.16: The completed compositing network for merging all the elements together.

Then, we combine different elements from background to foreground together by using the merge node in Nuke. The node acts as the mix function mentioned in Section 3. We put all the elements together in the following order: background buildings, midground buildings, midground boats, foreground buildings and foreground boats. In order to match the multi-point perspective in Chinese paintings, a transform node is applied to each element before we merge everything together. The transform node can perform a standard translate operation to the image which allows the user to control the translate value in horizontal and vertical direction. In this way, the user can re-arrange the layout easily in Nuke. After that, we multiply the result with a rice paper texture. Finally, we add atmospheric effects into the painting by using the Zdpeth pass. Figure 4.16 shows the compositing network for combining all the

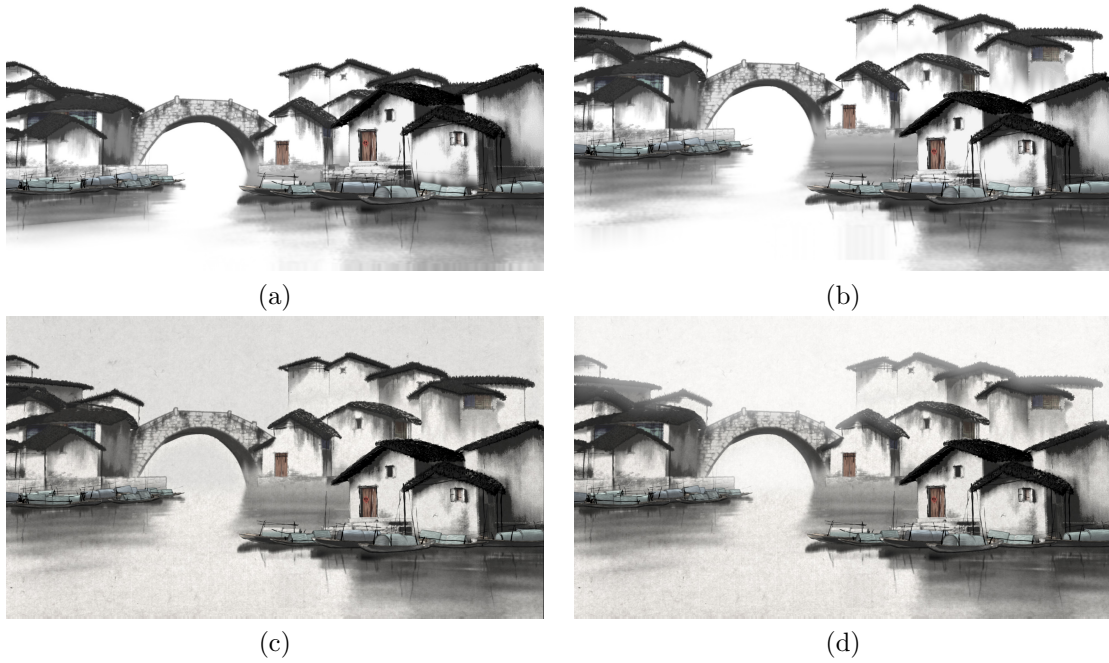


Figure 4.17: A series of images showing the process of merging all different elements together to create the final painting.

elements together.

Figure 4.17 shows a series of images for the compositing progress. Figure 4.17(a) is the initial result after we simply merge all the elements together. Figure 4.17(b) shows how we can use the transform node to re-arrange the layout. Figure 4.17(c) shows the result after multiplying the render with a rice paper texture. And Figure 4.17(d) shows the final result with atmospheric effects.

4.4 Create Another Lighting Design

In this section, we discuss the process of creating another lighting scenario based on some of the important film lighting aesthetics rules mentioned in Section 2.2. The purpose is to demonstrate our artistic intention for this research by changing the lighting in our 3D Chinese painting to achieve some of the goals of good film

lighting design.

As mentioned in Section 2.2, the five important fundamentals of good lighting design are:

- Directing the viewers' eye
- Creating depth
- Conveying time of day and season
- Enhancing mood, atmosphere and drama
- Revealing characters' personalities and situations

In this section, we choose the first three fundamentals for demonstration, because they are the principles most commonly applied to outdoor landscape scenes. In the following two subsections, we will first discuss how we set our visual goals and strategies for re-lighting the painting based on lighting references. And next, we will talk about the process of adjusting virtual CG lights and compositing parameters to get the final result.

4.4.1 Set Visual Goals

First, we set our visual goals for the final re-lit painting. These goals need to match the first three fundamentals of good lighting design which are: (1) Directing the viewers' eye. (2) Creating depth. (3) Conveying time of day and season. We use three still images from films as our lighting references which successfully demonstrate each fundamental with its lighting design.

For the first fundamental, Figure 4.18 shows a still image from the film “Blade Runner” as our lighting reference, in which lighting design is used to direct viewers' eye to the foreground characters. In this shot, the lighting designer creates a strong

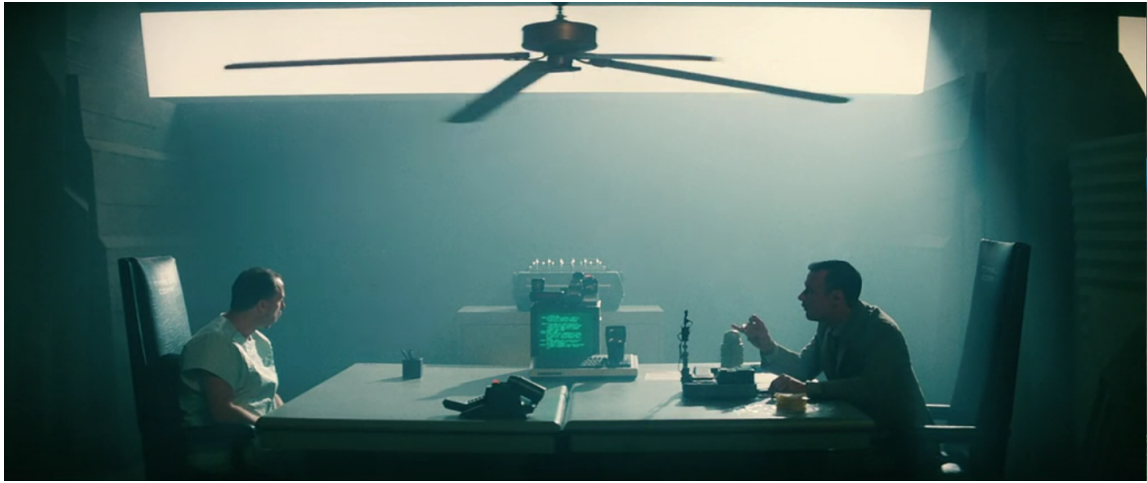


Figure 4.18: A still image from the film “Blade Runner” demonstrating how lighting design can direct viewers’ eye [7].

atmospheric effect in the background and uses a low key lighting on the character, which creates a high contrast between dark and light on the character. This helps to direct viewers’ eye to the most important subject in this shot. In our case, we choose the foreground buildings and boats as our focus point and try to direct the viewers’ eye to them. The lighting design will implement the similar method in our reference, in which we will create a strong atmospheric effect behind the foreground and also make the foreground darker in order to create more contrasts.

For the second fundamental, our goal is to create the sense of depth from foreground to background elements. We use another still frame from the film “Blade Runner” as our reference (see Figure 4.19). In this shot, the lighting artist uses a heavy atmospheric effect in the background which gradually fade out when it gets to foreground, which successfully convey the distance between foreground and background. The atmospheric effect creates a transition from dark to light. In our 3D painting, we will use the same technique of putting atmospheric effects in background to convey depth, which is already discussed in the previous paragraph.



Figure 4.19: A still image from the film “Blade Runner” demonstrating how lighting design can create depth [7].

For the third fundamental: conveying time of day and season. We use a still image of a morning scene from the film “Pride and Prejudice” as our lighting reference (see Figure 4.20). In this shot, the main light source, which is the sun, is illuminating the scene from the back side. From the camera, we can clearly see the sun light is shining from a very low angle from the backside of the forest which helps to convey the time of day. In our case, we will use the same method of changing the direction and position of the key light to create a morning scene in the 3D Chinese painting.

As a summary, our re-lit 3D Chinese painting will be a morning scene with heavy atmospheric effects in the midground and background. The main focus point will be the foreground buildings and boats.

4.4.2 Adjust Virtual CG Lights and Compositing Parameters

After setting our visual goals and methods by studying the lighting references, we start to adjust our virtual CG lights and compositing parameters to re-light the 3D painting.



Figure 4.20: A still image from the film “Pride and Prejudice” demonstrating how lighting design can convey time of the day [19].

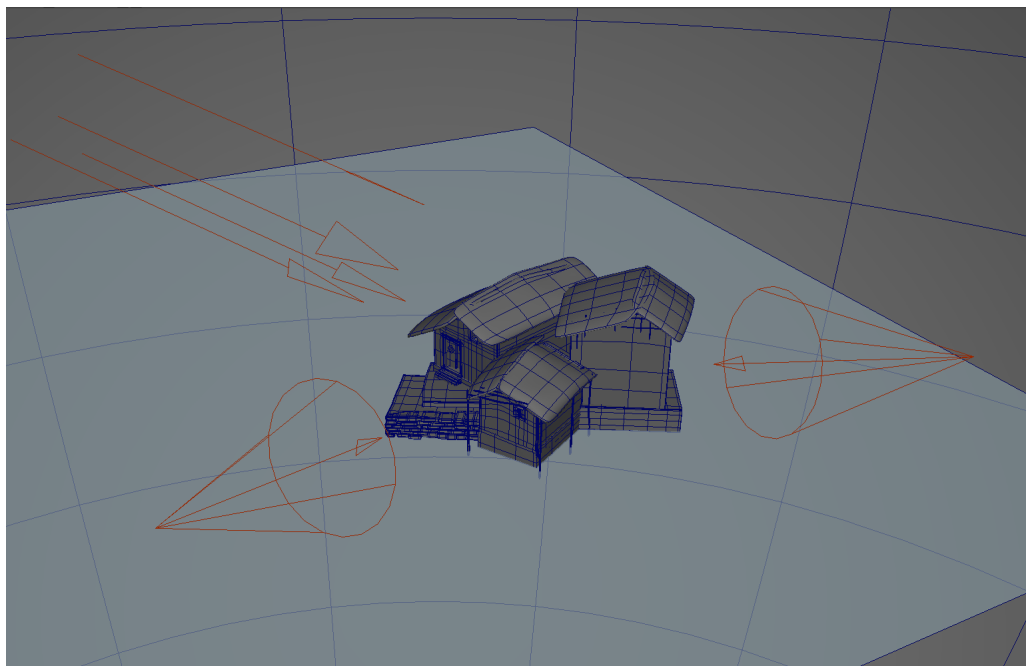
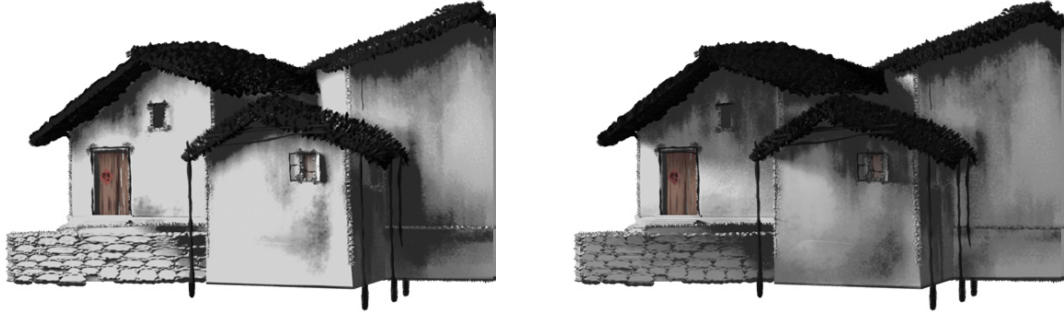


Figure 4.21: A screenshot from the 3D scene showing how the lights are placed to create a back-lit scene.



(a) A render of the foreground buildings with the old lighting set-up (b) A render of the foreground buildings with the new lighting set-up

Figure 4.22: Comparison of the old and new lighting results.

First, we change the lighting set-up in our 3D scene by adjusting the direction and intensity of the key and fill lights to create a back-lit effect similar to our reference (see Figure 4.20). Figure 4.21 shows how the lights are placed in our 3D scene. And Figure 4.22 shows two images of how the old and new lighting set-ups. By comparing the shadow direction, we can clearly tell in the new lighting set-up (see Figure 4.22(b)), the subjects are lit by a low angle light source from the back.

Besides adjusting the virtual CG lights in 3D to get a different lighting result in our beauty pass, we can reuse all the other passes because they do not change with lighting. Then, we go through the same process mentioned in Section 4.3 to assemble all the different passes together (see Figure 4.23(a)).

Since we have custom controls for color grading and atmospheric effect in our composite network, we can easily adjust the contrast and value of specific element. Therefore, to create a heavy atmospheric effect in the midground and background, we highly reduce the contrast and lift the value of all the midground and background elements. However, we keep the high-contrast in the foreground buildings and boats.



(a) Basic compositing result of assembling all the passes in Nuke.



(b) Final result for the morning lighting scene after adding the heavy atmospheric effects.

Figure 4.23: Two images showing the result before and after applying color grading.

Figure 4.23 shows two images of the result before and after the color grading in Nuke.

4.5 Results

The final result of this study is a short animation sequence of a 3D Chinese landscape painting. Figure 4.24 shows two frames from the final animation.

The animation is a morphing from one classical Chinese painting lighting scenario to another lighting design based on film lighting aesthetics to demonstrate the artistic intention. Figure 4.24(a) shows one frame from the final animation “Jiangnan”, in which a front-lit lighting design was used. While in Figure 4.24(b), the key light source was placed in the back and a lower angle to mimic a morning lighting condition. More atmospheric and depth effects are used to create a higher contrast in foreground and a much lower contrast in midground and background. The changes in light helps to create a totally different mood and story point for the painting.



(a)



(b)

Figure 4.24: two individual frames from the final animation “Jiangnan”, in which two different lighting designs are used to demonstrate the artistic intent of this research

5. CONCLUSION AND FUTURE WORK

In this research, we explore the method to transfer the unique visual characteristics of Chinese ink-and-brush paintings into 3D computer graphics, as well as the artistic possibility of applying film lighting aesthetics in Chinese paintings to enhance visual story telling.

We primarily use Yang Ming-Yi’s landscape paintings as our visual references. First, a careful visual analysis is done in the following aspects: value and tone, shape and form, water reflection, layout and composition. The analysis abstracts the essential visual characteristics of the paintings. Then, a series of shading and rendering solutions are proposed to match each visual characteristic in 3D computer graphics.

By using a combined solutions of NPR shading in 3D rendering and digital compositing discussed in this research, we are able to create a living Chinese ink-and-brush painting in 3D computer graphics, which both preserves the essence of the original art form and portrays more depth and three dimensional feeling by using procedural animations and camera movements.

Our NPR shading method uses both 3D rendering and 2D image processing algorithms to match the Chinese ink-and-brush painting aesthetics in CG. This approach turns out to be effective in matching the visual characteristics from the analysis in Section 3. Although this approach does provide artists efficient controls in the final image, the process still requires lots of human efforts like custom adjustments in shading parameters and hand-painted textures. Future researches could focus on how to implement this method in a more procedural and seamless way which requires less adjustments by hand while still achieve the same artistic quality.

In Section 3.2, we mention that methods in this research is focusing more on capturing the visual aesthetics of Chinese paintings, and care less about simulating realistic result of how ink diffusion looks on rice paper. Therefore, the results can be improved by simulating ink diffusion. Another extension can be in expressing a wider range of materials. The approach in this study effectively provides the essential visual characteristics of Chinese paintings. However we did not explore using a variety of materials with different reactions to light. It can, therefore, be useful to study how Chinese painters express material properties and include these materials into our process.

Finally, this research explores and tests the effectiveness of applying film lighting aesthetics in Chinese ink-and-brush paintings to enhance visual-storytelling by using 3D computer graphics. This opens a door for filmmakers to create films in such visual style.

REFERENCES

- [1] Anthony Apodaca and Larry Gritz. In *Advanced RenderMan: Creating CGI for Motion Pictures.*, pages 456–479. San Diego, California: Academic Press, 2000.
- [2] Sharon Calahan. *Ratatouille*. Walt Disney Pictures, Pixar Animation Studios, 2007. videodisc.
- [3] Ching Chan, Ergun Akleman, and Jianer Chen. Two methods for creating chinese painting. In *Computer Graphics and Applications, 2002. Proceedings. 10th Pacific Conference on*, pages 403–412. IEEE, 2002.
- [4] Francois Cheng. *Empty and Full, The Language of Chinese Painting*. Shambhala Publication, Inc., 1994.
- [5] Adrian David Cheok, Zheng Shawn Lim, and Roger Thomas KC Tan. Humanistic oriental art created using automated computer processing and non-photorealistic rendering. *Computers & Graphics*, 31(2):280–291, 2007.
- [6] Nelson S-H Chu and Chiew-Lan Tai. Moxi: real-time ink dispersion in absorbent paper. In *ACM Transactions on Graphics (TOG)*, volume 24, pages 504–511. ACM, 2005.
- [7] Jordan Cronenweth. *Blade runner*. The Ladd Company, 1982. videodisc.
- [8] Maggie Cross. *The Art Of Chinese Brush Painting*, chapter 3, pages 40–45. The Crowood Press, 2011.
- [9] Pawe Edelman. *Oliver twist* (2005 film). TriStar Pictures, 2005. videodisc.
- [10] Aaron Hertzmann and Denis Zorin. Illustrating smooth surfaces. In *Proceedings of the 27th Annual Conference on Computer Graphics and Interactive Tech-*

- niques*, SIGGRAPH '00, pages 517–526, New York, NY, USA, 2000. ACM Press/Addison-Wesley Publishing Co.
- [11] Au Ho-Nien. The characteristic and spirit of chinese paintings. University Lecture, 2004. <http://www.uindy.edu/asianprograms/articles.php>.
 - [12] Shen-Wen Huang, De-Lor Way, and Zen-Chung Shih. Physical-based model of ink diffusion in chinese paintings. 2003.
 - [13] Yong Duk Jhun. Kung fu panda. DreamWorks Animation, 2008. videodisc.
 - [14] John Kahrs. Paperman. Walt Disney Animation Studios, 2012. videodisc.
 - [15] Xunxiang Li and Yu Li. Simulation of chinese ink-wash painting based on landscapes and trees. In *Plant Growth Modeling and Applications, 2006. PMA'06. Second International Symposium on*, pages 328–334. IEEE, 2006.
 - [16] Yang Ming-Yi. *As Time Goes By: Paintings by Yang Ming-Yi*. Yan Gallery, 2001.
 - [17] Yang Ming-Yi. *Jiangnan: Paintings by Yang Ming-Yi*. Tianjin Yangliuqing fine art press, 2006.
 - [18] Xie Ning, Hamid Laga, Suguru Saito, and Masayuki Nakajima. Contour-driven sumi-e rendering of real photos. *Computers & Graphics*, 35(1):122–134, 2011.
 - [19] Roman Osin. Pride and prejudice (2005 film). StudioCanal, 2005. videodisc.
 - [20] Psyop. Twinings sea, 2011. <http://www.psyop.tv/twinings-sea/>.
 - [21] Youetsu Sato, Tadahiro Fujimoto, Kazunobu Muraoka, and Norishige Chiba. Stroke-based suibokuga-like rendering for three-dimensional geometric models ten and shun touches. , 3(4):224–234, 2004.

- [22] Chung-Ming Wang and Ren-Jie Wang. Image-based color ink diffusion rendering. *Visualization and Computer Graphics, IEEE Transactions on*, 13(2):235–246, 2007.
- [23] Der-Lor Way, Yu-Ru Lin, Zen-Chung Shih, et al. The synthesis of trees in chinese landscape painting using silhouette and texture strokes. In *WSCG*, volume 10, pages 499–507, 2002.
- [24] Der-Lor Way and Zen-Chung Shih. The synthesis of rock textures in chinese landscape painting. In *Computer Graphics Forum*, volume 20, pages 123–131. Wiley Online Library, 2001.
- [25] Yangmu Wu. In *The Techniques of Chinese Painting.*, pages 15–18. New York: New Amsterdam Books, 1990.
- [26] Zhao Xiaoding. House of flying daggers. Edko Films, 2004. videodisc.
- [27] Songhua Xu, Min Tang, Francis Lau, and Yunhe Pan. A solid model based virtual hairy brush. In *Computer Graphics Forum*, volume 21, pages 299–308. Wiley Online Library, 2002.
- [28] IkSuk Yang, YoungJung Yu, and DoHoon Lee. Ink-and-wash painting based on the image of pine tree using mean curvature flow. In *Proceedings of the 11th ACM SIGGRAPH International Conference on Virtual-Reality Continuum and its Applications in Industry*, pages 189–194. ACM, 2012.
- [29] Wu Yangmu. *The Techniques of Chinese Painting.* New Amsterdam Books, 1990.
- [30] JinHui Yu, GuoMing Luo, and QunSheng Peng. Image-based synthesis of chinese landscape painting. *Journal of Computer Science and Technology*, 18(1):22–28, 2003.

- [31] Young Jung Yu, Young Bok Lee, Hwan Gue Cho, and Do Hoon Lee. A model based technique for realistic oriental painting. In *Computer Graphics and Applications, 2002. Proceedings. 10th Pacific Conference on*, pages 452–453. IEEE, 2002.
- [32] Qing Zhang, Youetsu Sato, JY Takahashi, and Norishige Chiba. Simple cellular automaton-based simulation of ink behaviour and its application to suibokuga-like 3d rendering of trees. *The Journal of Visualization and Computer Animation*, 10(1):27–37, 1999.